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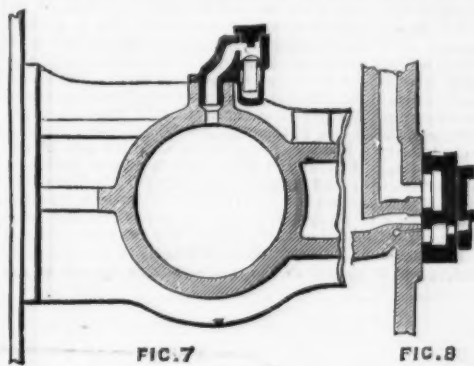
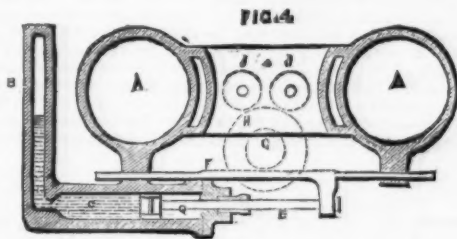
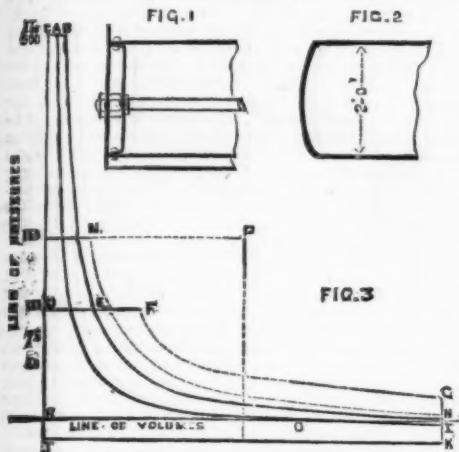
COMPRESSED AIR LOCOMOTIVE.

At a recent meeting in London of the Institution of Mechanical Engineers, Mr. Scott-Moncreiff read a paper as above. The author first recounted the various objections which have long been urged against the use of steam on tramways and the working of steam tramway engines. He next gave his reasons for think-

ing that in many cases compressed air tramway engines could be used with advantage, and even with economy. In this reasoning, however, there was nothing which has not been previously urged against steam engines and in favor of compressed air, though it was admitted that that motor should be adopted which was most cheaply and efficiently available, and that in some cases this would be the steam engine. He then described at great length the various circumstances and conditions of the design of a tram-

car with engines, receivers, and other gear, as indicated in Figs. 5 and 6. The wheel base is 5 ft. Three cylindrical receivers, each 2 ft. in diameter, and of the overhanging space, or 8 ft. in length, are used at each end. These were first made as shown in Fig. 1. By means of a process of welding by gas jets, receivers are now made as at Fig. 2. The working pressure is about 22 atmospheres, but the receiver was tested to 750 lb. on the square inch. In working an engine with compressed air from a receiver, a tolerably uniform resistance has to be overcome by a constantly decreasing pressure of air. The disadvantage of working by reducing the pressure before the air passes into the cylinders is that it entails the loss of a great amount of energy. See Fig. 3. Starting with a reduced pressure of 100 lb. per square inch, as against the 300 lb. initial pressure, the loss of energy is represented at first by four times the area, B C D E, for every revolution of the wheels, in the case of a two-cylinder, double-acting engine. This area will decrease with the decreasing pressure, and the gross loss is great. Again, where the pressure is reduced as low as one-third of

point upon the scale of pressures. If engineers expanded air far enough so that the exhaust took place at the pressure of the atmosphere, the loss of heat would be only the mechanical equivalent of the work done in the cylinders, without the additional loss of temperature at the end of the stroke, which occurs when a residual pressure is left to communicate momentum to the atoms composing the elastic medium. The writer found this to be the case by experiment, and thus showed that troubles from the formation of ice could only arise when the air escaped from the cylinders above the pressure of the atmosphere. Fig. 4 shows an apparatus devised for the purpose of automatically altering the range of expansion. A A are the engine cylinders. In



the initial pressure, there is a great loss attending heavy work in consequence of late cut-off and high pressure exhaust. Compressed air in receivers cannot be dealt with by reducing the pressure before using it without a great loss of power. In the diagram isothermal lines have been chosen to illustrate the meaning, on account of their simplicity. If adiabatic curves had been taken, allowing for the thermal equivalent of the work done in the cylinders, the same remarks would have applied to them at a higher

chamber, B, is air at the pressure in the receiver. C is a chamber filled with a liquid so as to provide a hydraulic instead of a pneumatic connection with the piston, D, which moves backward or forward as the pressure upon either side of it is increased or diminished. The piston rod, E, is attached to a toothed rack, F, acting upon a pinion, G, which revolves with the wheel, H; and this in its turn gives a rotary motion to the pinions, J J, keyed to the valve spindles. These spindles, being turned to the right or left, give motion

to the valves, which are thus opened or closed at the proper point in the stroke of the piston. The pinions, J J, are also keyed to the valve spindles, which are turned to the right or left, giving motion to the valves.

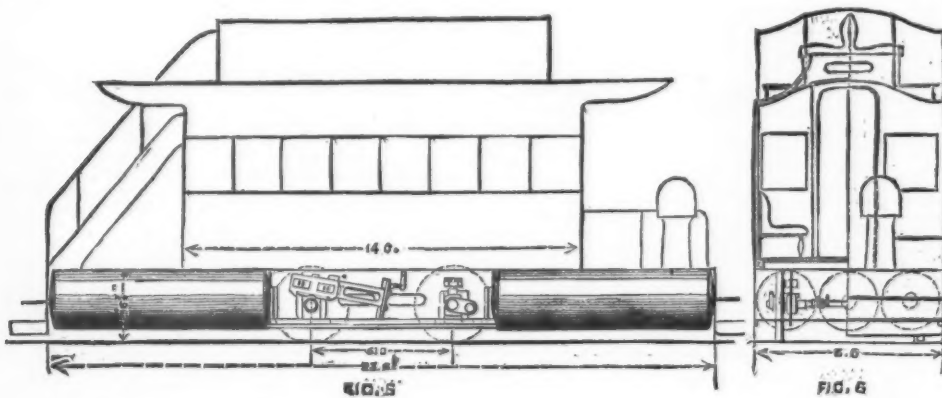


THE BEAUMONT IMPROVED COMPRESSED AIR LOCOMOTIVE FOR STREET RAILWAYS.

to cut-off valves placed upon the backs of the main valves, by altering their relative positions through the agency of right and left hand screws. In this way the movements of the piston, D, are conveyed directly to the valves, so as to vary the period of cut-off in accordance with the position of the toothed rack. Turn now to the diagram, Fig. 3. It will be seen that a mean pressure of 60 lb. will be given by the outer black line, B H, if the initial pressure is 300 lb., and exhaust at the pressure of the atmosphere. This mean pressure can only be obtained when the reservoir pressure has fallen to 100 lb. by cutting off at one-fourth instead of one-twentieth of the stroke. The pressure of the receivers, during the process of pumping, is admitted to the forward end of the piston, D, Fig. 4, in the space, Q, and therefore, as the pressure rises it forces back the piston until the motion is arrested by the confined air in the chamber, B. Suppose the maximum pressure in the receiver and the piston, D, back so that the valves are adjusted to their earliest points of cut-off; and then, as the pressure in the receivers begins to diminish, the piston will be moved forward by the superior elasticity of the confined air in the chamber, B, and the point of cut-off will be rendered correspondingly later. When the pressure has been reduced in the receivers by one-half, the pressure of the air confined in B, being correspondingly diminished, its volume will have doubled. Hence the toothed rack would have moved through half its stroke, and would thus have moved the valves half way toward their latest point of cut-off. When the pressure is reduced from 150 lb. to 100 lb., the point of cut-off requires to take place at very nearly one-fourth instead of one-eighth of the stroke, in order to give the required mean pressure of 60 lb. But at 100 lb. the volume of the confined column of air in the chamber will have increased in the ratio of 3 to 1, and the piston, D, if its area is four times that of the air-chamber, will only have moved through one-sixth of its stroke instead of one-fourth. It is evident that if a mean pressure of 60 lb. is necessary to propel the vehicle at a certain desired speed, and if a cut-off at one-fourth of the stroke is necessary when the initial pressure is 100 lb. in order to obtain the requisite mean pressure, then the expansion apparatus, cutting off at one-sixth, will have the effect of lessening the speed of the vehicle. Thus toward the end of the journey it becomes necessary to alter the rate of expansion obtained from the automatic apparatus, which is only correct for about two-thirds of the total fall of pressure—that is to say, from 300 lb. to 150 lb. This later cut off is obtained by a two-way valve attached to the pipe that communicates between the receivers and the chamber in front of the piston, D. If this valve is turned so that the communication is closed to the receivers and opened to the

initial pressure was 300 lb., must be increased. In short, if we take the capacity of the engines as unity when the mean pressure of 60 lb. is required in order to overcome an incline, we must at first reduce their capacity to say 0.6, in order to obtain the normal amount of work which is required on a level road, and at the same time terminate the stroke at the pressure of the atmosphere; and on the other hand, when the initial pressure is reduced to 100 lb., we must have an earlier cut-off if we are to finish at atmospheric pressure, and must increase the capacity of the engines above unity in order to make up for it. Now the expense of the fuel for driving the writer's car is only about a halfpenny per mile, when used on a large scale, and when furnace coals are to be obtained at 10s. per ton. The present car, as made for the writer by Messrs. Neilson & Co., Hyde Park Locomotive Works, Glasgow, travels seven miles with one charge of air at the moderate pressure of 26 atmospheres, and this with a load of forty passengers, and including about twenty-five stoppages and reversings of the engines. It is clear that the insignificant saving due to heating the air before passing it into the cylinder, as has been adopted by another inventor, is not worth having, at least on such a route.

Before the discussion on this paper commenced, Mr. Moncreiff gave some further explanation of the arrangement for automatically altering the range of expansion, and gave some reasons for objecting to the adoption of larger cylinders. Mr. Hughes discussed the three chief difficulties which the author had said attended the use of steam, namely—(1) Emission of products of combustion; (2) necessity for condensing the steam; (3) weight of water that must be carried for condensing. Briefly, Mr. Hughes's answer to these was—(1) The products of combustion caused no inconvenience on the large number of cars running in France and in this country; (2) there was no difficulty in condensing the steam sufficiently for all practical purposes; (3) the weight of water was no disadvantage, and often was of great advantage in increasing the adhesion on the rails, which would otherwise be insufficient on some gradients. The weak part of the air-propelled tramway engine was its want of range of power. It often happened that much more than the ordinary maximum hauling power was necessary, in consequence of snowy roads or breakdowns. As an instance he mentioned that, on one occasion, the brakes of an engine in Paris stuck fast, and the engine could not be got to move. Its stopping would have stopped the whole traffic for some time, if the engines had not a considerable range of power. This enabled the next engine that came up to raise steam in a few minutes to full pressure, and then push the disabled engine and its car, as well as hauling its own car, a long distance to a siding. This is a thing an air engine



atmosphere, the pressure in this chamber is instantly reduced, and the confined air in the chamber, B, immediately thrusts the piston, D, forward, so as to set the valves to a later point of cut-off. Turning to Fig. 3, it will be seen that many difficulties have still to be overcome. The ratio of the cubic contents of the chambers B and C, when arranged as 1 to 4, is only right for the purpose of explanation, besides being only correct for about two-thirds of the journey. The two areas must be adjusted so that the points of cut-off will give the required mean pressure for a corresponding series of adiabatic curves, in which allowance is made for the loss of energy in the air in the cylinders when it is doing work by expanding. Supposing the work to be constant, the dynamical area which must be added to the isothermal area, in order to allow for this work, will be a constant quantity. An adjustment of the two areas, B and C, to something less than the ratio of 1 to 4, must, therefore, be made, and this variation in the ratio between the cubic contents of the chamber, B, and the chamber, C, can always be adjusted by reducing or adding to the quantity of the liquid. On once more examining the isothermal lines, it will appear that there are yet further difficulties to be overcome. Hitherto we have dealt with a supposed maximum mean pressure of 60 lb., used to overcome a supposed maximum resistance. Now, if we look at the outer line, B H, Fig. 3, which starts from the line of maximum initial pressure, we find that it supplies the conditions of a mean pressure of 60 lb., terminating at the pressure of the atmosphere at the end of the stroke. Let us now turn, not to the maximum mean pressure required to overcome the maximum resistance, but to an average mean pressure required to overcome an average resistance. To use a mean of, say, 30 lb. instead of 60 lb., the point of cut-off at the maximum initial pressure of 300 lb. must be moved from B to A; and this earlier expansion brings the isothermal line across the atmospheric line at the point O, a little beyond the center of the line of the volumes, or, in other words, at about half the stroke of the engine. In this way a dynamical loss will occur, on account of the back pressure of the atmosphere, this loss being represented on the diagram by the area, H I O. When the pressure has dropped to 100 lb. it is necessary to bring the point of cut-off further in on the line of volumes than the point F, and in this way to terminate the isothermal line at the point H, on the atmospheric line, instead of at G, as to move the residual pressure at the end of the stroke represented by the height, G H. To do this the mean pressure must be reduced below the supposed maximum of 60 lb.; and to make up for this reduction the capacity of the engines beyond the capacity we started with when the

could not do; but things would happen on tramways which made a temporary application of extraordinary power necessary. As the author had said, the cheapest efficient system should be employed; and though he would not say that in some cases air might not be as cheap as steam, he could not admit the author's objections to steam engines, for the difficulties were not now with the engines but with the roads. With good strong tramways steam engines could be economically and advantageously used. Mr. Moncreiff had said that the shunting necessary with the steam hauling locomotive need not cause much, or any, more trouble than changing horses. He thought that the author must be credited with the solution of the problem, if air was to be employed.

Mr. D. Adamson referred to the compressed air car of Captain Beaumont, and said that the six-cylinder engine originally employed by him had now been altered to two cylinders of larger diameter, and all difficulty with refrigeration by expansion was simply overcome by heating the air a little when highly compressed, and indeed it was economical to use as high a temperature as the lubricants would admit, the maximum being controlled by the temperature to which it was necessary to raise high pressure air to prevent freezing upon exhaust. The temperature must not be high enough to drive off the lubricant. In Captain Beaumont's car, welded steel receivers 1 inch thick were used with a pressure of 1,000 lb. They were of such a size that this pressure gave a tensile strain of 8 tons per square inch.

M. Bourgeron read a telegram from Captain Beaumont, saying, among other things, that one of his cars weighing 12 tons, was successfully running at Leytonstone, and that the air was compressed to 1,000 lb. with 1 lb. of coal per cubic foot. Mr. J. Tomlinson, Jr., engineer of the Metropolitan Railway, said that he had made a few runs with the six-cylinder Beaumont car on his railway, and it was proved to be useless there, whatever it might be on tramways. The cost of hauling a train of 150 tons by the steam locomotives was only 1½d. per mile as compared with even Mr. Moncreiff's ½d. per mile for his one air propelled car weighing 7 tons 7 cwt. He had made an estimate of the cost of introducing such a system for the Metropolitan Railway, and found that twenty-six Cornish boilers, 40 feet in length, would be required night and day to provide compressed air for the engines that ran out of Aldgate alone. These, with the engines and machinery and other plant, would require about five acres of land, and altogether it would cost more than the whole of the engines on the line and their working for a long time. The air engine had no recuperative power, and for many reasons could not be successful for traffic such as that on the Metropolitan Railway.

COMPRESSED-AIR LOCOMOTIVE ENGINES.

AN important step has been made toward the mechanical working of tramways by the introduction of the Beaumont compressed-air engine on the Stratford and Epping Forest branch of the North Metropolitan Tramways. This engine comprises a store tank or reservoir for the compressed air, which is utilized in cylinders of small diameter, motion being given to the pistons by the expansion of the air in the cylinders and transmitted to the wheels by gearing. The reservoir is charged at a pressure of 1,000 lb. per square inch at the commencement of each journey.

An inspection of the air compressing machinery and of the working of the tramway engine was lately made, when the details were explained by the inventor, Colonel Beaumont, R.E. The compressing machinery consists of a fixed compound engine having a high pressure cylinder 12 in. in diameter, cutting off at half stroke and using steam at 95 lb. boiler pressure. The low-pressure cylinder is 20 in. in diameter. The air compressor is on what is known as the "stage" principle, the air being compressed in a series of cylinders of gradually decreasing diameter. From the compressors the air is conducted through about 250 ft. of 1½ in. iron pipe to the street in the Broadway, Stratford, where there is a flexible hose attachment for filling the reservoir on the engine. This operation occupies about fifteen minutes, during which time the compressing engine is working.

There is only one tramway engine running at present, but the compressing arrangements are equal to the supply of compressed air to four engines, working continuously. The tramway engine takes a tramcar to Leytonstone and back, and then stops a quarter of an hour to replenish its air supply, when it starts with another car, the intermediate journeys being performed by horses. On the occasion of the run last week, the engine, having brought in a car from Leytonstone, was replenished in a quarter of an hour, the pressure at starting being 1,000 lb. per square inch. The distance from Stratford to Leytonstone is two and a quarter miles and an ascent the whole way, the total rise being 88 feet, an incline of 1 in 25, and a curve of 50 feet radius being encountered at Maryland Point-bridge. The run was accomplished in twenty-two minutes, and on examination the gauge showed a pressure of 675 lb. per square inch, showing that 325 lb. of pressure had been used. On reaching Stratford on the return journey the gauge registered a pressure of 550 lb., indicating that 125 lb. more of air pressure had been used. The small power required on the return journey is accounted for by the fact that it is a falling gradient the whole way, so that at times air is not used at all.

The engine throughout ran with remarkable smoothness and with scarcely any noise. It has been on the road about a month, and it is stated that only at first horses were a little startled now and then at seeing a large vehicle moving along without horses and apparently without wheels, as they are boxed in. With regard to fuel cost, it is estimated that 23 lb. of fuel is used per train mile for hauling a gross weight of 13 tons, the engine weighing 9 tons and the car and passengers 4 tons, sometimes more if crowded. But it has to be observed that the compressing engine is standing for three-quarters of the day, only being required for a quarter of an hour out of every hour. Were there four tramway engines running it would be kept fully at work, and it is estimated that the consumption of fuel would then be reduced to about 9 lb. or 10 lb. per train mile. Should the system be permanently adopted on this, or, indeed, any other tramway system, it is intended to dispense with the independent engine, and to have a combined engine and tramcar. So far as the working of the Beaumont engine has proceeded, it is clearly demonstrated that air at a pressure of 1,000 lb. per square inch can be used with safety and without any difficulty or hindrance whatever. The next desirable step would be its adoption on the underground railways, for which it would seem to be eminently adapted.—*Illustrated London News*.

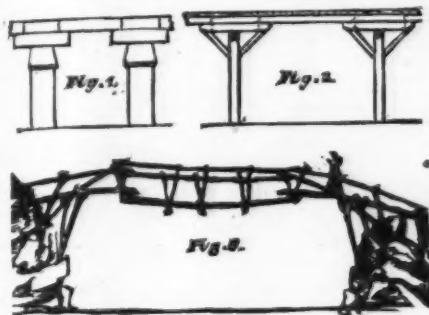
THE FORTH BRIDGE.

In sundry articles from time to time we have reviewed the antecedents of the above undertaking, and we are now in a position to illustrate and describe the design for a girder bridge by Mr. Fowler and Mr. Baker, which, with certain modifications suggested by Mr. Barlow and Mr. Harrison, the consulting engineers of two of the English railway companies interested in the project, has been definitely accepted for execution. The reference to the board of consulting engineers was of the widest scope, embracing projects for tunnels and for bridges with moderate spans and numerous piers as well as for different types of bridges of the exceptionally long span of that originally designed by Sir Thomas Bouch. A very short examination sufficed to clear the ground of the tunnel and short-span bridge projects, as the risks and contingencies in both instances proved to be incalculable under the special conditions of the Forth crossing.

In the hands of an inexperienced engineer an estimate for a bridge with short spans and frequent piers, however difficult, will almost invariably be found to work out far below that of a long span bridge, the reason of course being that a life-long experience in foundations of a varied and difficult character is required to enable an engineer to foresee and provide for all the contingencies pertaining to difficult subaqueous works. One example will suffice to illustrate this statement. We have before us Sir Thomas Bouch's original sketch and estimate for the piers of the Forth Bridge as authorized in 1865, that is to say, with spans of 500 ft. These piers were both loftier and of a larger base area than the St. Louis Bridge piers, and were proposed to be sunk to the same average depth below the surface of the water. The type of construction adopted by Sir Thomas Bouch was as novel as the most inexperienced could desire, and the estimate was most satisfactory—£10,740 for each pier! At about the same time Captain Eads and his engineers were elaborating the designs for the St. Louis Bridge, and being somewhat less sanguine than Sir Thomas Bouch, they put the cost of the two piers and the abutments of that work at £317,000, an average of, say, £80,000 instead of £10,000 per pier. The validity of the former estimate has been tested by facts, and so far from the amount proving to be excessive, Captain Eads, in his report to the directors dated October 1, 1871, had to explain how, from various unforeseen causes, the estimate had been exceeded by about 50 per cent., the cost of the piers and foundations being about £472,000, or at the rate of, say, £250 per lineal foot of bridge, instead of the £91 estimated by Sir Thomas Bouch as the probable cost, with piers of greater height and area of base in the same depth of water!

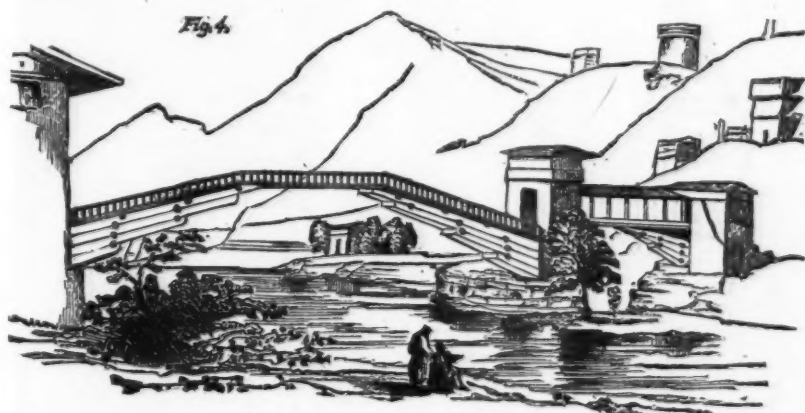
A little knowledge is proverbially dangerous, and especially so in subaqueous works. The inexperienced are tempted to embark on the dangerous sea of analogy, and con-

tend that because a certain work has been done under certain conditions without difficulty, therefore a modified work can be done under modified conditions also without difficulty. India affords many examples of deeply founded piers, but to the practical man who has had to deal with huge bowlders which must be probed for and cleared in advance of the cutting edge of the caisson, and with sloping peaks of rock which must be leveled down or the rest of the caisson edge be carefully underpinned before the rock can be cleared of sand and stepped, and who is familiar with the hundred other contingencies of subaqueous works in Europe and America, the deep well sinking in the uniform silt of our Indian rivers will afford no data at all either as regards cost or contingencies. It would be as sound to argue that, because certain individuals had walked some 600 miles in a week at the Agricultural Hall, they would have succeeded in covering that distance to the North Pole had they formed a part of Sir George Nares' late Arctic expedition. Fortunately the engineers to whom the question of the Forth Bridge design was referred were men of large and varied experience in subaqueous works, and Mr. Fowler, as consulting engineer to the Egyptian Government, was not likely to forget the disastrous experiences of the French engineers at the Barrage, involving a loss of a couple of millions sterling from an error in works of foundation which it was his



duty if possible to repair. In fact none of the engineers were likely to make the fatal error of under-estimating the cost and contingencies of pierwork in the Forth, where in some places bowlders of unknown weight would have to be removed to allow the caissons to descend, and in other places the fissured and steeply sloping trap rock would require to be cleared of untrustworthy fragments, and be stepped for the masonry, and as a consequence it was quickly decided to adhere to the original project of a long-span bridge with piers of a simple and well-tried character in a moderate depth of water, and of moderate and certain cost.

It only remained, therefore, for the engineers to investigate and discuss the relative advantages of different types of superstructure. Three types alone demanded consideration, namely, suspension, arch, and girder bridges of varied design. Of these the suspension type received first consideration, as it was desired to see whether the bridge, as designed by Sir Thomas Bouch and contracted for by Messrs. Arrol, could be so modified as to comply with the increased requirements of the Board of Trade as regards wind pressure and otherwise. It was found by Mr. Alan Stewart, who had worked out the details and made the calculations for the original suspension bridge, that an additional sum of £700,000 would have to be expended on Sir Thomas Bouch's design to make it a sufficiently strong work, and even then it was very doubtful whether any firm of experience and responsibility would undertake to erect it



under a guarantee contract. Mr. Barlow then brought his experience to bear, and devised a suspension bridge free from most of the defects of the previous design, and £300,000 less costly, but this in its turn proved to be nearly £300,000 more costly than the girder bridge designed by Mr. Fowler and Mr. Baker, which we illustrate by a page engraving this week. Bridges of the arch type were found to be unsuitable to the conditions of the case, the temporary works involved being of the most formidable character, the difficulties and risks of erection unparalleled, and there being no corresponding advantage in respect of cost. The result of the inquiry was, therefore, to satisfy the engineers that a continuous girder bridge was the cheapest and stiffest structure that could be designed for the Forth crossing.

Some little confusion of thought would appear to exist in many minds as regards this type of construction. Most people are willing to concede the antiquity of the arch and of the suspension system, but are doubtful whether the "continuous girder," if it be rechristened "cantilever and central girder," be not a modern and patentable invention. As a matter of fact it is a prehistoric arrangement.

In the earliest Egyptian and Indian temples will be found the stone corbel and lintel combination shown in Fig. 1, and in the oldest as in the most modern wooden bridges will be seen practically the same thing in timber (Fig. 2).

Skeleton bridges on the same principle have for ages past been thrown by savages across rivers. We give a sketch of one such on the route of the Canadian Pacific Railway

(Fig. 3). Perhaps one of the most interesting structures of this kind ever built is a bridge in Tibet, constructed about 220 years ago, and illustrated by Fig. 4.

The sketch is reproduced from a drawing made in 1783 by Lieutenant Davis, R.N., who formed part of the embassy to the Court of the Teshoo Lama in Tibet, an account of which, with illustrations, was published in London in the year 1800. The book was a popular one at the time, and was translated and republished in Germany, so that both English and German engineers had the opportunity eighty years ago of reading the following, probably the first description of a "cantilever and central girder" bridge ever published: "The bridge of Wandipore is of singular lightness and beauty in its appearance. The span measures 112 feet; it consists of three parts, two sides, and a center nearly equal to each other; the sides having a considerable slope, raise the elevation of the center platform, which is horizontal, some feet above the floor of the galleries. A quadruple row of timbers, their ends being set in the masonry of the bank, and the pier supports the sides; the center part is laid from side to side." Making allowance for difference of material the preceding work may fairly be looked upon as the prototype of the proposed Forth Bridge.

Descending to more recent times, it will be found that the term "cantilever and central girder" has ever been familiar as a household word to all educated engineers, because in treating on the strains in continuous girders it has almost invariably been the rule of authors to regard the structure as a central girder suspended from two cantilevers at the points of contrary flexure. Thus writing in 1850 on the Britannia Bridge (vol. I, p. 275) Mr. Edwin Clark premises severing the beam at the point of contrary flexure, and suspending the central portion from the "semi-beams or cantilevers," and appends the diagram (Fig. 5) in illustration of the resultant strains.

He also (vol. II, p. 493) gives a sketch (Fig. 6) of "shorter tube resting on brackets from the pier at either extremity, as below," which had been discussed by Mr. Stephenson in 1846.

In the former year also Mr. Fowler not only talked about severing the beam at the point of contrary flexure and suspending it, but had the experiment tried with a large wooden model, and the result was recorded in the discussion on the Torksey Bridge (Min. Proc. Inst. C.E., vol. IX., page 256).

In 1855 Mr. Barton, in a paper on the Boyne Viaduct (Min. Proc. Inst. C.E., vol. XIV., page 457), pointed out that the points of contrary flexure might be made to coincide with any previously determined points by severing the beam, and he added this most suggestive comment: "In very large spans, where it may be a matter of great importance to reduce the weight in the middle of the beam as much as possible, the quantity in material in the top and bottom tables as well as of the sides may be reduced to a minimum by throwing the points of contrary flexure toward the middle of the beam, the great weight of material being placed over the piers." This is exactly what has been done in the Forth Bridge girders.

In 1858, Mr. Latham, in his well-known work on wrought-iron bridges (page 222), also speaks of "a girder suspended from the cantilever girders," and in 1859 Mr. W. H. Barlow took out a patent with reference to that and other matters. He preferred making the depth at the pier $1\frac{1}{2}$ times the depth at the center. In the Forth Bridge the ratio will be 7 to 1 instead of $1\frac{1}{2}$ to 1.

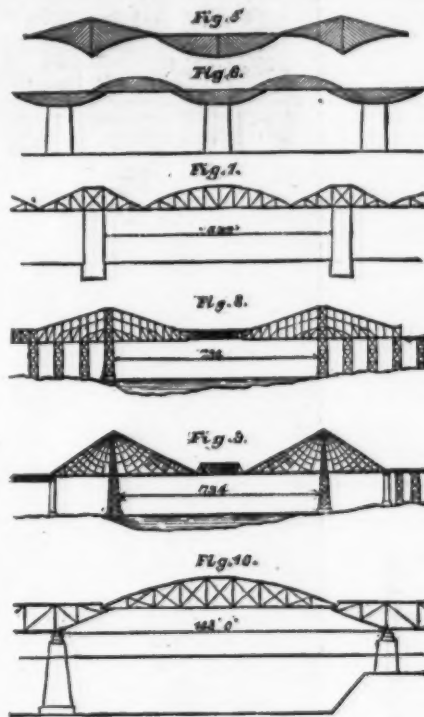
In 1863, Professor Ritter, of Hanover, in his justly popular work, "Dach-und-Brücken Constructionen" (chapter x.), again drew attention to the fact that "hinges can be employed with advantage in girder bridges," that a "great saving of material is effected by using a continuous girder and breaking the continuity by means of hinges." To enforce his conclusions he works out in full detail the stresses upon all of the members of a continuous girder bridge of 100 meters, or, say, 325 feet span of the type shown by Fig. 7.

In 1864, Mr. Sedley patented Lam Sabroo's bridge of the year 1643 done into iron, but spoiled it by certain unscientific additions. Thus instead of adhering to the cantilever and central girder system pure and simple as Lam Sabroo did, Mr. Sedley began by making his cantilevers too weak for their work, and then strengthened them by attaching suspension chains to their projecting ends, and not satisfied with this, he proposed to make the central girder act as a strut between the ends of the cantilevers, so that this structure might act also as an arch. Of course Mr. Sedley was not an engineer, or he would have known that the three systems of continuous girder, arch, and suspension, each admirable in its way, will not act together, in consequence of changes of form from the elasticity of the material and variations of temperature. This unscientific combination was, however, modified by the bridge builders consulted by Mr. Sedley, and several little foot, or light road bridges were built for Mr. Sedley on the true continuous girder principle. Mr. Sedley, therefore, deserves credit for advertising and promoting, in a commercial sense, the cantilever and central girder type of bridge, though he was in error in assuming that there was any novelty in the combination, since, as we have shown, it was in use from time immemorial on a small scale, while as large a bridge as any built by Mr. Sedley was erected more than two centuries ago by Lam Sabroo, in Bootan, and hundreds of examples may be found spanning continental canals. Again, the theory of the subject was exhausted by Mr. Edwin Clark in 1860, and by every suc-

ceeding writer, and even if there had been anything patentable about it, the patent was secured by Mr. Barlow five years in advance of Mr. Sedley. The latter gentleman, however, did not make so great a mistake as Mr. E. W. Young, who in 1865 innocently patented the "forming joints or hinges in bridges on the bracket or cantilever principle, and forming the central portion of a girder."

The preceding facts are illustrative of what we have termed the confusion of thought respecting the continuous girder or cantilever and central girder system, which is really as old as either the arch or suspension system, though perhaps less familiar to most persons.

In 1864 Mr. Fowler and Mr. Baker designed a steel bridge of 1,000 feet span on the said system for the proposed South



Wales and Great Western Direct Railway Severn Crossing, but the span was subsequently reduced to 600 feet. An act was obtained for the construction of the bridge, and the contract was let, but owing to financial difficulties the work was not proceeded with.

In 1867, Mr. Baker enforced the economical advantages of the continuous girder of varying depths in a series of articles on "Long Span Bridges" (*Engineering*, vol. III.), which went through three editions in this country, and were republished at Philadelphia, and translated into German and Dutch, and published in the Transactions of the Austrian and Dutch engineers respectively.

In 1871, Mr. Fowler and Mr. Baker made designs and estimates for a bridge across the Severn, comprising two girder spans of 800 feet each; and in 1873, Mr. Baker, at the request of the Corporation of Middlesbrough, designed the superstructure for a proposed ferry bridge across the Tees, which included a 650 foot span on the same system (*Engineering*, vol. XVI., page 60).

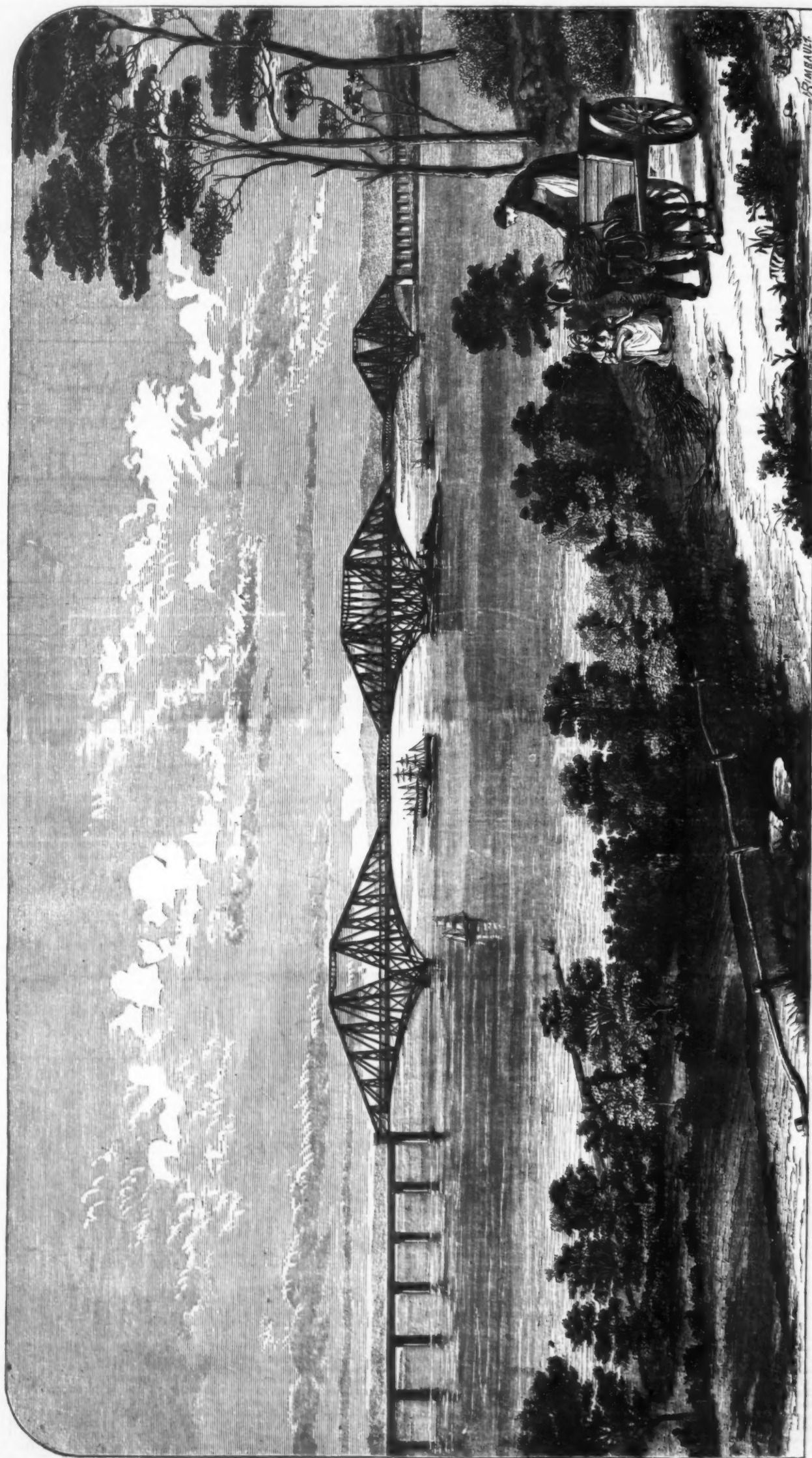
In 1876, nine competitive designs were submitted for the proposed New York and Long Island Bridge, comprising one span of 734 feet, and one of 618 feet, and of the three premiated designs two were on the aforesaid system (Figs. 8 and 9). The first was the design of the Delaware Bridge Company, and the second of Colonel Flad, the very able engineer who, under Captain Eads, carried out the great St. Louis steel arch bridge.

In the same year was built the first, and so far as we know, the only railway bridge of the type under discussion (Fig. 10). This is a bridge of 148 feet span across the Warthen, near Posen. It might appear strange at first that the application to railway purposes of so well-known a system should have been deferred until 1876, but the explanation is that there are thousands of bridges in existence on the continuous girder, or in other words, cantilever and central girder principle; but engineers as a rule have elected not to sever the bridge at the point of contrary flexure, or to make the girders of varying depth.

A glance at the preceding illustrations and description will satisfy our readers that there is nothing novel or untried in the principle of the structure designed for the Forth crossing. The reasons dictating the design in the Forth Bridge are those which probably influenced the Red Indians in making the structure illustrated by Fig. 3—economy of material and facility of erection. It must be conceded, however, that except as regards principle the design is essentially novel, but the novelties are dictated by the unexampled size of the structure, and are due simply to the perfect adaptation of the principle of the continuous girder and the general laws regarding the strength of materials to the special conditions of the case. Thus it will be observed that the structure is a continuous girder of varying depth on plan as well as elevation, the central girder portion being of the ordinary width required for a double line of rails, and the cantilevers spreading out to an extreme width of 112 feet at the piers. By this means the stresses on the horizontal bracing from wind pressure are much reduced, and lightness and compactness are attained. To further the same ends the whole of the vertical members are made of two struts inclined toward each other from base to summit, and braced together. To reduce the extreme height of the structure, and bring the center of gravity as low down as possible, the bottom members of the continuous girder are curved, springing from solid masonry piers at a height of 18 feet only above high water, whereas in the original design the main chains, carrying, of course, all the weight, were supported at a height of 550 feet above the same point! The main compression members are steel tubes ranging up to 12 feet in diameter, the tubular form being adopted for two reasons, first, because experiments have shown that inch for inch the tubular form is stronger than any other, and, secondly,

CONTINUOUS STEEL GIRDER BRIDGE TO CROSS THE FIRTH OF FORTH.

DESIGNED BY MR. JOHN FOWLER AND MR. BENJAMIN BAKER.



because the amount of stiffening and secondary bracing is thereby reduced to the lowest percentage. It might be thought that columns 350 feet in length were an untried novelty, but this is not so, as we have the precedent of the Saltash Bridge oval tubes, 16 ft. 9 in. by 12 ft. 3 in. in diameter and 400 ft. in length, the strain upon which under the test load was higher per square inch than will be that on the steel columns of the Forth Bridge. The central girder portion is simply an ordinary double-line railway bridge of 500 feet span, with girders of a type intermediate between the girder of parallel depth and the bowstring. This is an economical type, and many Continental bridges have been so constructed, among which may be mentioned the Kuilenburg Bridge of 492 feet span, the Hommel of 408 feet, and the fine bridge across the Waal, near Nijmegen, which includes three spans of 426 feet,

3. That no untried material be used in its construction, or in other words that no steel be employed which would not comply with the requirements of the Admiralty, Lloyd's, and the Underwriters' Registry, as determined by the experience gained in the use of many thousands of tons of steel plates, bars, and angles for shipbuilding purposes.

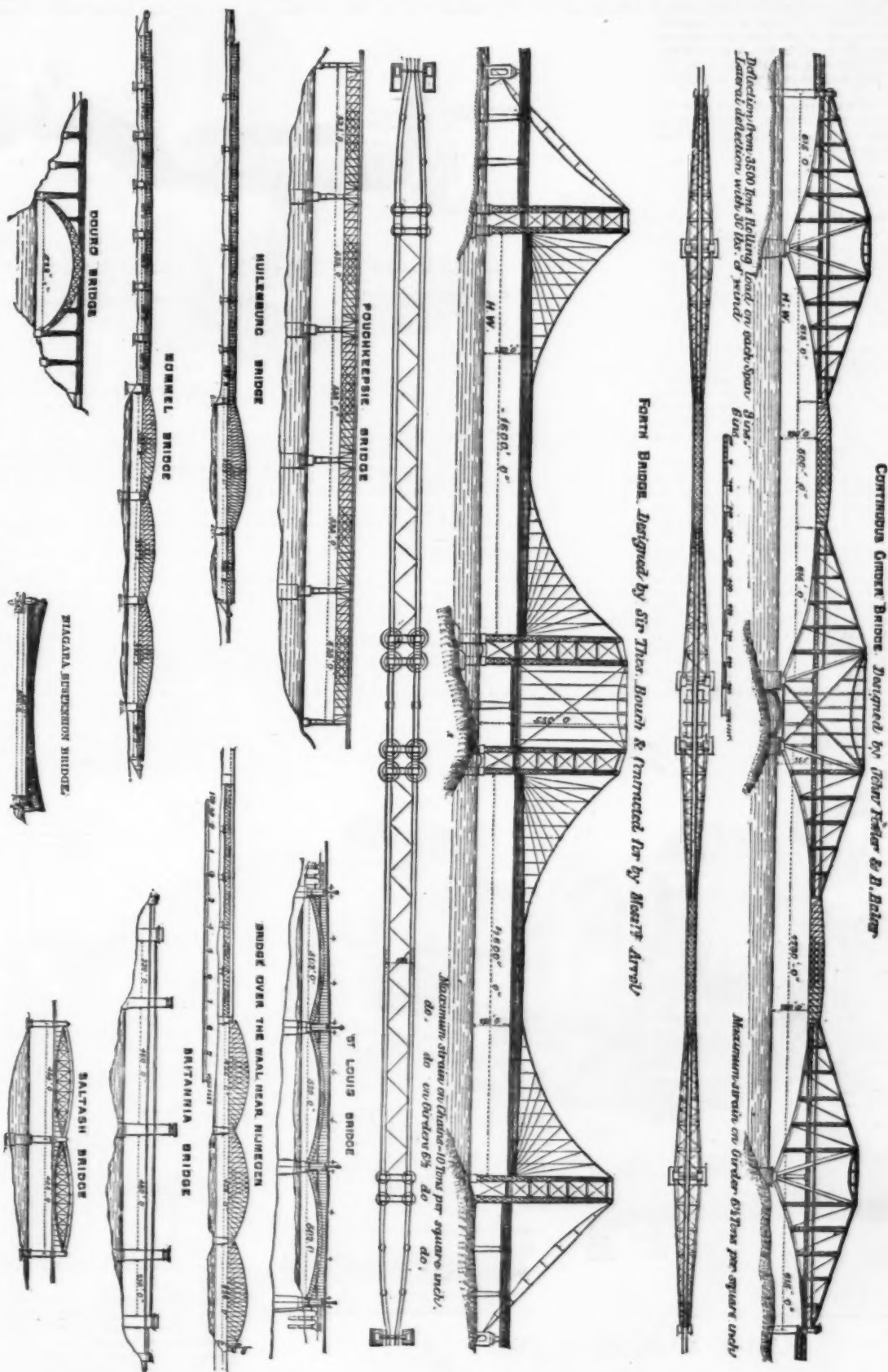
4. That the maximum economy be attained consistent with the fulfillment of the preceding conditions. We think it will be apparent to most engineers and bridge builders that the original suspension bridge design complied with none of these conditions, while the girder design complies with all.

As regards rigidity each span is calculated to carry a rolling load of 3,500 tons, and the deflection under the passage of an ordinary 400 ton goods train would be little more

girders 30 feet deep. No temporary works were used for the central span, but in arches, of course, heavy and costly back ties have to be provided, and the difficulties in joining up the overhanging halves were found in the instance of the St. Louis and the Douro bridges to be not inconsiderable. In the Forth Bridge these would not arise, and the details of the operations are of the simplest character.

As regards material nothing but the highest quality of Bessemer or Siemens steel, as used for riveted work in shipbuilding, will be employed, and the strain will be limited to 6½ tons per square inch. It has already been stated that the continuous girder bridge proved on investigation to be the cheapest type of construction for the Forth Bridge, and therefore it may be said that the whole of the desiderata are attained in that design. Of course the details are subject to

COMPARATIVE DIAGRAMS OF LARGE-SPAN RAILWAY BRIDGES.



with main girders in less than one sixth of the span, or 71 feet in depth.

The chief desiderata in the Forth Bridge, which is the largest railway bridge ever yet proposed to be built, are clearly as follows:

1. The maximum attainable amount of rigidity, both vertically under the rolling load and laterally under wind pressure, so that the work when completed may by its freedom from vibration gain the confidence of the public, and enjoy the reputation of being not only the biggest and strongest, but also the stiffest bridge in the world.

2. Facility and security of erection, so that at any stage of erection the incomplete structure may be as secure against a hurricane as the finished bridge.

than an inch in the 1,730 foot span, and should the wind ever blow with a force of 30 lb. per square foot over the whole surface—a pressure probably sufficient to derail any train in motion—the lateral deflection would be the inappreciable amount of 6 in., or in other words the rails would be curved laterally to a radius of 140 miles. As regards erection the cantilever portion would be built by overhang, each successive bay being added and braced together vertically and horizontally with the permanent bracing as the work proceeds. Experience has amply proved that few contingencies attach to this mode of erection. One of the most recent examples is Mr. Shaler Smith's fine Minnehaha Bridge across the Mississippi, having a center span of 324 feet, erected by overhang, and two side spans of 270 feet, with

modifications, as the borings and other preliminary works are still far from complete, and as already stated, certain modifications suggested by Mr. Barlow and Mr. Harrison have been accepted by all parties. The matured design will, however, not differ in any essential point from that now illustrated. It will, undoubtedly, be a relief to engineers, contractors, and railway companies alike to be finally quit of the suspension principle, and to have to deal only with the well-tried girder system. Experience has proved that, whatever previous calculation may indicate, the amount of vibration pertaining to the suspension system is in practice always excessive. The antecedents of the latter type are not encouraging. Thus the gatekeeper of the Menai Suspension Bridge stated that during the storm of January 28,

1886, the undulatory motion of the platform at a point midway between the center and the pier was no less than 16 feet. In contrast with this it may be mentioned that the maximum movement of the Britannia tubes during the heaviest gales, as observed by Mr. Edwin Clark, was only $\frac{1}{4}$ inch. Whereas, as in the case of the Niagara Bridge, the only railway suspension bridge in the world, although stiffening girders, inclined ties, and other arrangements are introduced to mitigate oscillation and wave motion, it is found that the combination is too lively to permit of the transit of high-speed traffic. A load limited to a single train, a speed limited to a walking pace, necessitate a very different structure to a test load of 3,500 tons and a working speed of a Scotch express, especially when one structure crosses a sheltered inland gap and the other an exposed estuary. It will not fail to be observed by practical erectors that the girder bridge is made good by lateral bracing piece by piece as the work proceeds, while a suspension bridge would be swaying about in an imperfectly secure condition until the whole structure was complete. Great responsibility and anxiety must attach to the engineers and contractors of this gigantic work, however carried out, and we feel sure that engineers generally, both in this country and abroad, will join with us in hoping that a great success may be achieved.

We give, for purpose of comparison, diagrams of the original and amended designs for the Forth Bridge, and of the principal large bridges at present in existence on both sides of the Atlantic.—*Engineering.*

AMATEUR MECHANICS.

EASILY MADE SLIDE REST.

WHILE the most of the work to be done on the foot lathe may be accomplished as expeditiously and quite as well without a slide rest as with it, yet there are some operations that are greatly facilitated by means of this tool. Boring, for example—a very difficult thing to do with hand tools—may be done quickly and accurately by using a slide rest. In gear cutting—described in another part of this article—a slide rest is essential.

In the case of this tool, as well as others previously described, the purchase of a well-made article is recommended. Yet, if one has time and feels so inclined, he may make a really efficient slide rest with no other tools than his lathe and ordinary turning tools. Figs. 1 to 3 inclusive represent a slide rest that may be made in this way, Fig. 1 being a perspective view, and Figs. 2 and 3 respectively longitudinal and transverse sections of the tool carriage.

The T-shaped casting, A, has a longitudinal slot, which is made T-shaped in cross section to receive the head of the bolt that confines it in position upon the plate fitted to the lathe bed. The vertical ears at opposite ends of the casting are bored to receive the ends of the rods, B, upon which the tool carriage, C, slides.

The first operation in making the slide rest is to make one side of the casting, C, perfectly plane. It is then chucked in the lathe with the plane side next the face plate. Three holes are bored through it, two for the rods, B, and a smaller one for the screw, G. It is then chucked on an angle plate, so that the holes for the rods, B, are equally distant from the center line of the lathe, and the hole for the rod, D, is bored very carefully to insure the parallelism of its sides. The casting, A, is now placed upon a plane surface, and the casting, C, is clamped to the ear at one of its ends, and adjusted so that a line drawn through the center of the holes is

exactly parallel with the bottom of the casting. The casting, C, is used in this manner as a template for drilling both of the ears for the reception of the rods, B. It will be necessary to exercise great care in drilling these holes, as it is of vital importance to have the rods, B, perfectly parallel. The casting, C, may now be tapped to receive the screw, G, and the tool-carrying bar, D, may be fitted to its place, and turned down and threaded to receive the internally threaded boss of the wheel, E. This boss is fitted to the base of the casting, C, and is grooved circumferentially to receive a split ring, F, the latter being drilled to receive the ends of three screws that project through the casting into it and prevent the boss of the wheel, E, from moving lengthwise of the hole, while the arrangement permits of the free rotation of the wheel. The bar, D, has a head which is drilled ver-

ically to receive the tool post, and is provided with a heavy feather at the top, which is received by the slot formed by sawing into the upper portion of the casting, C. To render the bearing of the bar, D, somewhat adjustable, two screws pass through the casting above the feather. The tool post is of the usual description, having a loose collar above the head of the bar, D, and a nut below it. The mortise for receiving the tool extends a little below the loose collar, so that when the tool is clamped the post and ring will also be clamped. A slot is cut through the bottom of the casting, C, into each of the guide rod holes to permit of adjustment in case of wear by means of the screws which pass transversely through the slot. The ends of the rods, B, are fastened by a similar device. The screw, G, is prevented from end motion by a shoulder on the outside of the ear at the crank end, and a collar on the inside. The rods, B and D, may be made of steel or of cold rolled iron; the latter will be true enough without turning. The casting may be either of brass or

by the accompanying engravings. One consists in locating the holes by using paper scales which are printed from engine divided plates, and are therefore very nearly accurate. The other consists in dividing the plate by aid of a large paper disk graduated by hand.

For the most of purposes four rows of holes will answer. The best number of holes for the different rows is as follows: 240, 200, 144, 132. 240 can be divided as follows: 120, 60, 48, 40, 30, 20, 15, 12, 6. With 200 divisions: 100, 50, 40, 25, 20, 10, and 5 may be made. 144 divides into 72, 48, 36, 24, 18, 16, 12, 9, 8, 6. 132 into 66, 44, 33, 22, 11.

The best method of dividing an index plate of which the writer has any knowledge, aside from duplicating another, or using a dividing engine, is shown in next page. A wooden block, A, is attached to the face plate of the lathe by means of screws, and turned down truly on the face and upon the edge. A portion of the edge is turned to a suitable diameter for receiving a certain length of paper scale, C. The other

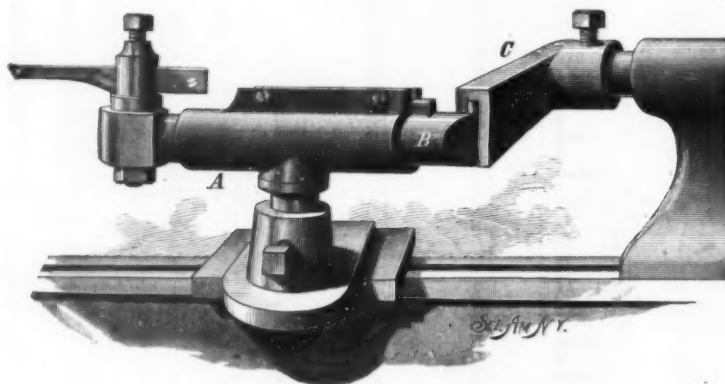


FIG. 4.—BORING ATTACHMENT.

Iron; a good quality of iron will perhaps prove the most satisfactory. The slots may be cut with the saws described in a former article. The tools to be used with the slide rest have also been previously described.

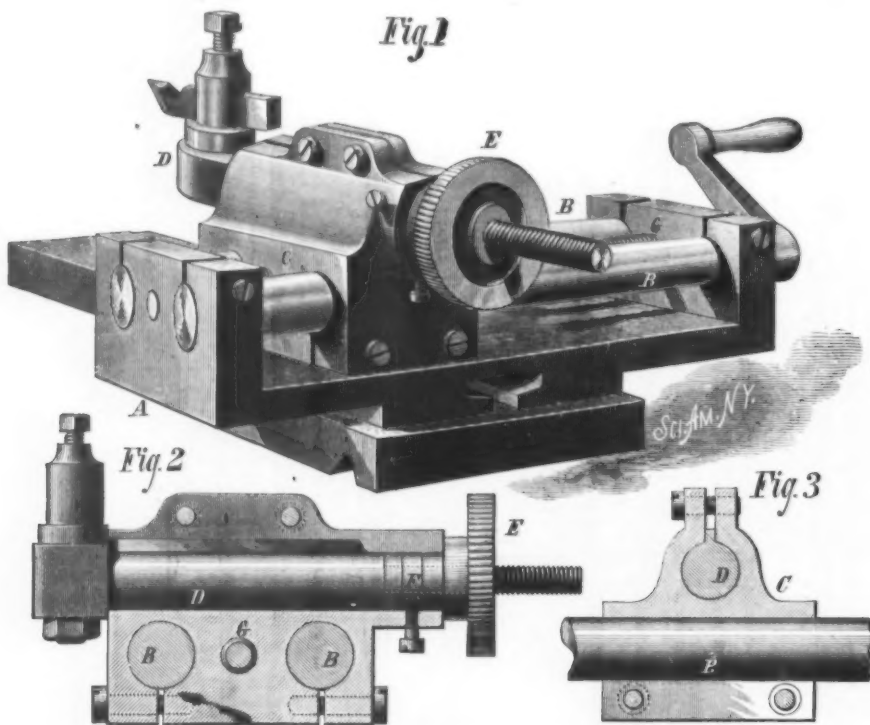
In Fig. 4 is represented a boring device which will be readily understood without special description. The casting, A, is fitted to the tool rest socket and provided with a sliding bar, B, which is like the bar, D, in the slide rest above described, excepting that its back end is rounded and provided with a pin which slides in the slotted arm attached to the tail spindle of the lathe by which it is moved, instead of having a moving device of its own. With this tool, boring and some kinds of outside turning may be done. It is less expensive than the slide rest and answers a good purpose.

INDEX PLATES FOR GEAR CUTTING.

There are many amateurs who would make their own gear wheels were it not for the expense of purchasing or the trouble of dividing and drilling the index plate, which is the

portion of the edge is pressed by a brake shoe, F, which is kept up by a screw in the standard, D. An index, E, is slotted and secured to the top of the standard, D, by a screw. To the face of the block, A, is secured the index plate, B, and in front of the plate there is a drill support which takes the place of the ordinary tool rest. The drill is capable of longitudinal as well as rotary motion in its support; it is driven by a belt from the drive wheel of the lathe, and is pushed forward a limited distance by the handle swiveled to the end of the drill spindle. The size of the drill will be governed altogether by the size of the plate; but in any case it should be as large as possible, always bearing in mind that the space between the holes should be of sufficient width to insure the required strength.

That portion of the wooden block, A, which receives the paper scale, C, is carefully turned so as to permit the ends of the scale to abut; the scale being very carefully cut so that its ends will join accurately and render the graduations of the scale uniform throughout. The scale is best attached to the block by means of paper tacks or small screws. For the greatest number of graduations given above, a two foot paper scale, or two pieces of shorter scales, will be required. The inches should be divided into tenths. The block should be 7-64 inches in diameter where it is surrounded by the



EASILY MADE SLIDE REST

exactly parallel with the bottom of the casting. The casting, C, is used in this manner as a template for drilling both of the ears for the reception of the rods, B. It will be necessary to exercise great care in drilling these holes, as it is of vital importance to have the rods, B, perfectly parallel.

The casting, C, may now be tapped to receive the screw, G, and the tool-carrying bar, D, may be fitted to its place, and turned down and threaded to receive the internally threaded boss of the wheel, E. This boss is fitted to the base of the casting, C, and is grooved circumferentially to receive a split ring, F, the latter being drilled to receive the ends of three screws that project through the casting into it and prevent the boss of the wheel, E, from moving lengthwise of the hole, while the arrangement permits of the free rotation of the wheel. The bar, D, has a head which is drilled ver-

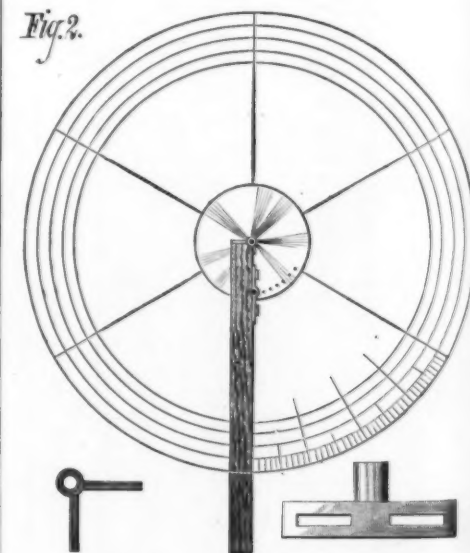
principal item in the apparatus required in cutting small gears.

Of course an index plate may be purchased, but the money thus laid out would go a long way toward paying for cutting all the gears that would ever be required by most amateurs.

It is admitted that it is difficult to obtain absolute accuracy by ordinary methods, but the plans here suggested will probably give as nearly perfect results as can be obtained without copying another index plate or using a dividing engine.

The index plate, before being divided, should be nicely turned and fitted to the place it will occupy on the lathe. This will generally be on the larger side of the cone pulley.

Two methods of graduating an index plate are illustrated



INDEX PLATES FOR GEAR CUTTING.

scale. The diameter of that part engaged by the brake shoe is not limited to any particular size.

It is obvious that for drilling 240 holes every mark on the scale must be brought opposite the index, E, and stopped by means of the brake, F, while a hole is drilled. After drilling this row of holes, the row containing 144 holes should be drilled, leaving a space between it and the 240 row for the 200 row. For the 144 row the operation is the same as that already described, except that a scale divided into twelfths is used, and alternate graduations only are noticed, the intermediate ones should be crossed out, so that the scale will really be a scale of inches divided into sixths. For the 132 row the block is turned down to 7 inches diameter, and the scale last used is shortened to 22 inches and again applied to the block and used as before.

After completing these rows of holes the drill is moved to the space between the first and second rows, the block is turned down to 6-38 inches, and 20 inches of the paper scale first used (inches divided into tenths) is employed. Every graduation on the paper scale is used in this case as in the first instance. This gives 300 divisions.

The paper scales recommended for this purpose are those used by engineers and draughtsmen. They may be obtained for a few cents from any dealer in mathematical instruments.

In Fig. 2 the larger circle represents a disk of paper which is carefully divided into large spaces by means of ordinary dividers, and the large spaces are subdivided in the same way.

In the center of the paper disk is placed the plate to be divided, and from the center of the plate rises a stud, to which is accurately fitted the sleeve attached to the end of the radius bar. The radius bar extends beyond the outer circle on the paper disk, and carries an adjustable sleeve, to which is accurately fitted a drill which may be rotated by means of a small drill stock. The sleeve that forms the

Either iron or brass may be used for the disk. The latter works the easiest and will answer every purpose.

GEAR CUTTING APPARATUS.

The index plate, A, is attached to the larger of the pulleys on the mandrel of the lathe by means of three or four screws, and the stop, C, provided with a point well fitted to the holes in the plate, is held in position on the bed plate, B, by a screw passing through a slot in the foot into the bed piece. The stop, C, is capable of springing sufficiently to admit of withdrawing the pin from the hole in the plate, and it is strong enough to hold the plate without vibration. Two standards, G, mounted on the plate, B, support pulleys over which the driving belt runs. The gear cutter head consists of a casting, D, fitted to the tool post of the slide rest, and

it occupies about the same position, in relation to the tool post, that the point of an ordinary turning tool does. The cutter, F, is shown in Fig. 4, enlarged. The upper view represents the side, the lower view the edge of the cutter. It has but a single tooth and is adapted to brass and similar alloys only. It may be sharpened by grinding. When iron or steel is to be cut the cutter should have several cutting edges, and the mandrel, E, should have a larger pulley, as more power will be required and the speed must be slower. By setting the slide rest at an angle bevel gears may be cut.

HINTS ON MODEL MAKING.

It is a simple matter for an experienced instrument maker or machinist to produce a fine model with turned shafts, cut gearing, true pulleys, and smooth working cams, but it is quite another thing for an inventor, without tools or materials, to embody his ideas in a working model even though he may have a mechanical taste.

It is fair to suppose that every mechanical inventor in these days of cheap machinery possesses some sort of a lathe, as these indispensable machines are now made for prices within the reach of almost any one.

It is quite evident, from an inspection of the models of the Patent Office, that most inventors who undertake to make their own models expend a great deal of labor without corresponding results. In the matter of gearing, for instance, one will whittle his wheels in wood, another will borrow his gearing from some defunct clock, while still another will purchase ready-made wheels from one of our well known firms making a business of furnishing parts of models.

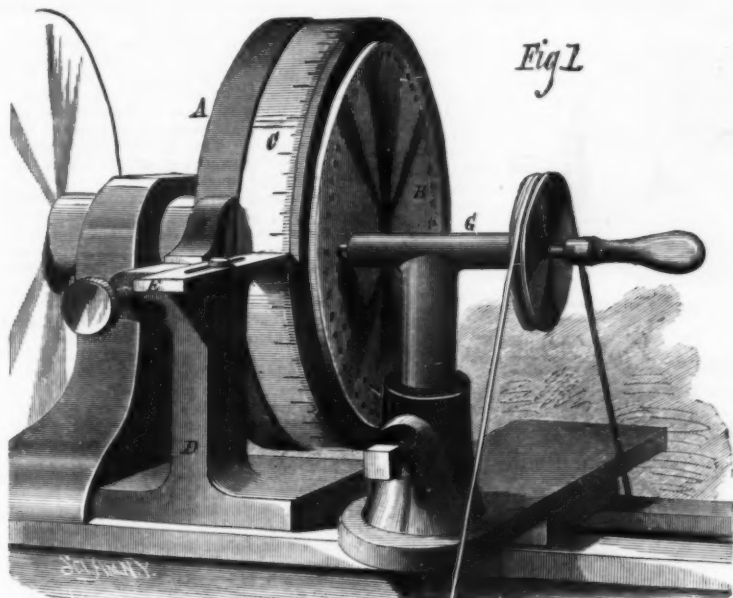
Of the three methods of obtaining the gearing the latter is undoubtedly the best, as all that is necessary to be done, in case of the cast gear wheels, is to bore them and file up the teeth, and as the cut gear wheels are generally bored, the shaft may be fitted without further work on the wheels. It is, however, seldom absolutely necessary to use toothed gearing, as rotary motion may be readily transferred by suitable friction wheels or by grooved or sprocket wheels and a round belt.

Figs. 1 and 2 show a form of friction gearing which is both simple and effective. The larger wheel is simply a disk of sheet brass having rounded edges, and boss spun or soldered on, and a smaller wheel consists of two swaged disks of steel having their convex faces separated by a metal washer a little thinner than the large wheel. These three members are secured to a common boss by spinning the end of the boss partly over one of the disks, as shown in the sectional view, Fig. 2. This form of friction gearing is noiseless and runs strong enough for the requirements of almost any model.

Figs. 3 and 4 show a form of sprocket wheel which is readily made and is almost as positive in its action as gearing. In this case the two wheels are alike; they consist of disks of sheet metal nicked to a uniform depth from the edge, and the arms thus formed are bent alternately in opposite directions, forming a groove for receiving the round belt used in transferring motion from one wheel to the other. It is evident that a belt cannot slip on a wheel of this construction.

Fig. 5 shows a form of friction gearing for transferring motion at right angles, and for imparting a variable speed to a shaft from another shaft running at a uniform rate. The large wheel in this instance is merely a plane disk of metal mounted in the manner already described. The smaller wheel is a grooved metal pulley surrounded by an elastic rubber ring. This is pressed with more or less force against the metallic disk, and its speed may be varied by moving it toward or away from the axis of the disk.

As to the matter of irregular motion usually imparted by cams, it is difficult to make a cam in the ordinary way with the milling machine, and there appears no very simple way



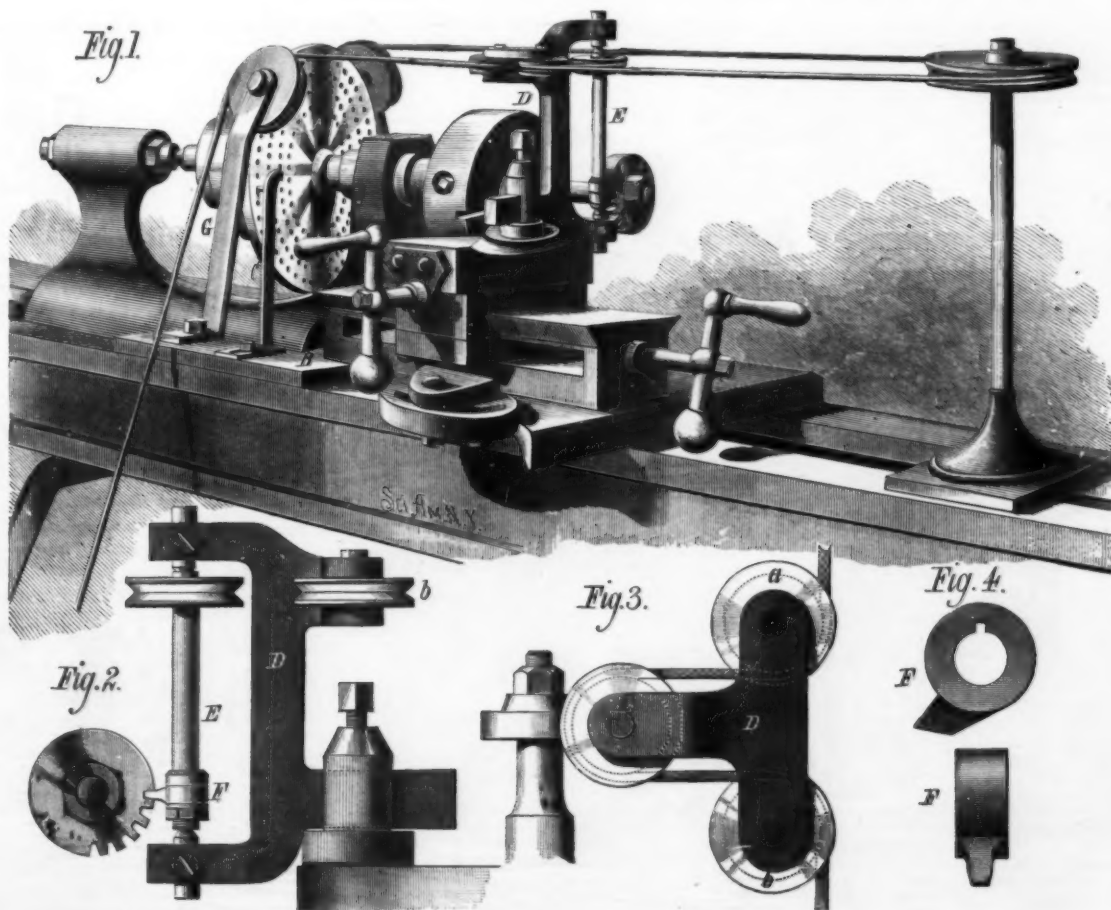
METHOD OF GRADUATING INDEX PLATES.

bearing of the radius bar is shown in detail in the lower left hand corner of the engraving, and the sleeve that receives the drill is shown in the opposite corner.

While drilling, the radius bar is held in place by a weight or by means of a clamp. After drilling each hole the bar is moved forward one space and secured by the weight or clamp. When one row of holes is completed, the sleeve which guides the drill is moved toward the center of the disk, and the operation of drilling is carried on as before. By this method whatever errors may exist in the graduations on the paper disk are greatly reduced in the index plate, and the plate produced will be accurate enough for most purposes if the work on the paper disk has been carefully done. The smallest plate should be at least three sixteenths of an inch thick, and the holes should not be drilled quite through.

the mandrel, E, provided with a pulley and mounted on carefully fitted centers in the casting. The casting, D, has upon opposite sides, near the upper end, ears (as shown in Fig. 3) for receiving the pulleys, a, b, which guide the driving belt, so that the cutter may be removed across the face of the wheel, being cut without changing the tension of the belt. The extreme end of the loop formed by the belt is supported by the pulley, H, mounted on a standard rising from the lathe bed. The standard may be placed far enough from the slide rest to admit of putting the tail stock between it and the slide rest in case it should be necessary to use the tail stock for supporting the work.

The mandrel, E, is provided with a collar and a nut for clamping the cutter, F. It will be noticed that the cutter comes exactly opposite the line of the lathe centers, and that



APPARATUS FOR GEAR CUTTING.

of cutting them from solid castings. There is, however, a simple way of building them up from readily obtained materials.

Fig. 6 shows a cam consisting of a cylinder of brass or a short section of brass tubing provided with two heads and mounted on a shaft. The cam groove is laid out on this surface, and two parallel pieces of square brass wire are soldered to the surface of the cylinder, or fastened by means of screws. They are placed uniformly distant throughout the entire circumference of the cylinder.

Fig. 7 shows a cam built up in the same way on the face of a disk.

As to shafts, the model maker may save himself much labor and expense by using Stubb's steel for small shafts, and cold rolled iron for larger ones. Either the steel or iron may be bought in one and three foot lengths.

Almost anything in the way of parts of models may be purchased ready for use, so that all the inventor need do is

toria Park. They are four in number, and each contains three sitting-rooms, good kitchen premises, abundant bedrooms, and all conveniences. They are built of good red local bricks, and roofed with Broseley tiles. The timber-work is red deal, and portions of the plaster filling are enriched with carving. Messrs. T. & H. Herbert, builders, of Leicester, are carrying out the work under the superintendence of Messrs. Goddard & Paget, M.M.R.I.B.A.—*London Building News*.

THE STRENGTH AND FIRE RESISTING QUALITIES OF BUILDING STONES.

The recent destruction by fire of a so-called fire-proof warehouse, has called attention to the strength and durability of our building stones. Dr. Hiram A. Cutting, of Vermont, (whose valuable and interesting experiments to determine the heat resisting power of various building stones, were

	(3.)	(4.)
Granites.....	800° to 950°	At or below 1,000°
Sandstones.....	900° to 1,000°	1,000° to 1,200°
Massive limestones.....	900° to 1,000°	Mostly 1,200°
Marbles.....	1,000° to 1,200°	1,200°
Conglomerates.....	800° to 900°	900° to 1,000°

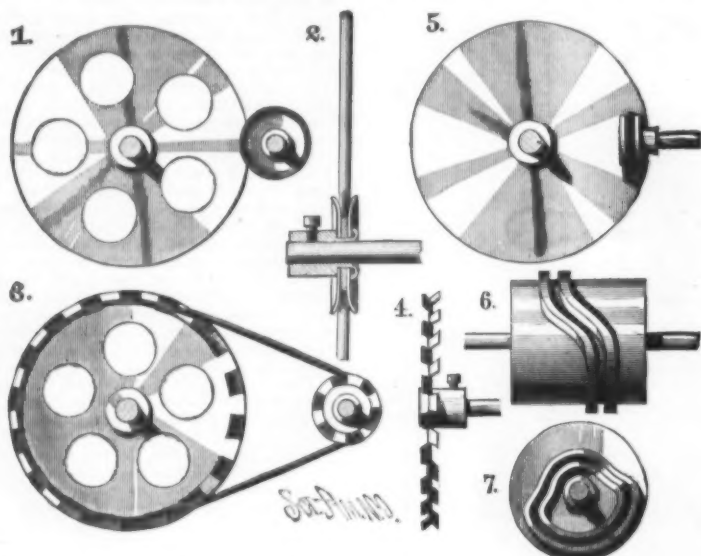
The granites had a specific gravity between 2.000 and 2.737, excepting one from Stanstead, Canada, of 2.833; and immersion in water added to their weight, through absorption, from 1.280th of their weight to 1.818th. In the case of sandstones, the specific gravity is 2.168 to 2.661, but mostly under 2.400; and the absorption was 1.17th to 1.80th, excepting two giving 1.240th (a freestone from Nova Scotia) and 1.314th (the Montrose stone, Ulster County, New York). For the marble the specific gravity is 2.666 to 2.848, and the absorption 1.300th to 1.380th; for the more solid of the pure massive limestones the specific gravity is 2.478 to 2.706, and absorption 1.280th to 1.480th.

The strength of the building stones used in this country has been investigated by crushing tests at the Columbia School of Mines, at the Navy Yard in Washington, and in other places. The results of these tests show, says the *Sun*, that the strongest of our building stones are the trap rocks of New Jersey and Staten Island, which bear a pressure of 24,000 pounds. They are not much used, however, owing to the cost of working, except where the blocks may be fitted together roughly.

The strongest granites come from Westerly, R. I., Richmond, Va., and Port Deposit, Md. These severally will stand a pressure of 17,750, 21,250, and 19,750 pounds to the cubic inch. Granite is the most durable of all stone in every-day use. The fine red polished granites, so much used of late, come from Peterhead, near Aberdeen, Scotland, and the Bay of Fundy, and to all intents and purposes they last forever. The strongest marbles come from Lee, Mass., and bear 13,440 pounds to the cubic inch; Tuckahoe, N. Y., 12,910 pounds, being stronger than the Bay of Fundy granite, which stands a pressure of only 11,813 pounds to the cubic inch. Italian marble will bear 11,250 pounds, and the statuary marble from Carrara only 9,723 pounds pressure to the cubic inch. Good rough marbles are found in Westchester County. The strongest limestone comes from Kingston, N. Y. It will resist 13,900 pounds to the cubic inch, and has the greatest variety of color of all building stones. That from Glens Falls takes a high polish and is jet black. Gray comes from Lockport, and the delicate cream and dove tints are found in the Athens and Caen stones. Lighter shades are found in the Bermuda and Florida rock.

The gray Lockport stone when dressed by the hammer resembles a light granite, and is consequently used for trimming brick houses. The cream-colored limestone of the Paris basin is very soft at first, and would be esteemed by a green hand unfit for any purpose, but it hardens when dressed, and the most delicate work can be done, the exposure that would chip the work in other stones being its preservative. The Topeka stone, now much used from Kansas, possesses the same valuable property. It can be sawed like wood in any shape. The limestones that are most valued, however, in this country, come from Dayton, Ohio; they are greatly used by Cincinnati builders. In Chicago the favorite limestone is the Athens, before mentioned, from northern Illinois. These were deposited by the great sea of the Niagara period of geology.

The lighter stones come from the Ohio, and belong to the lower carboniferous. A medium between the two in color comes from Amherst. Both are excellent as resisting fire. Many of the finest buildings in Cincinnati are built of the Waverley sandstone, of a light dove color. Other rich stones are the St. Genevieve from Missouri, straw colored and finely grained. All these stones will stand a greater pressure than is ever demanded of them, 50,000 pounds to the square foot being, perhaps, the maximum. The pillars of All Saints Church at Angiers sustain a pressure of 86,000



TRANSMITTING AND CONVERTING MOTION.

to combine them and mount them on a suitable frame; but even so simple a matter as a wooden frame for a model sometimes proves troublesome.

The small tenons and mortises are difficult to make, and the frame to be strong enough to bear handling must be made so heavy as to be entirely out of proportion. A simple and easy method of securing the joints of small frames is to clamp the parts in the position they are to occupy in relation to each other, and then drill, with a sharp twist drill, two holes through one piece from side to side and into the end of the abutting piece, then inserting two hard wood pins, having previously coated them with glue. This makes a joint far stronger than the mortise and tenon, and it is very quickly done.

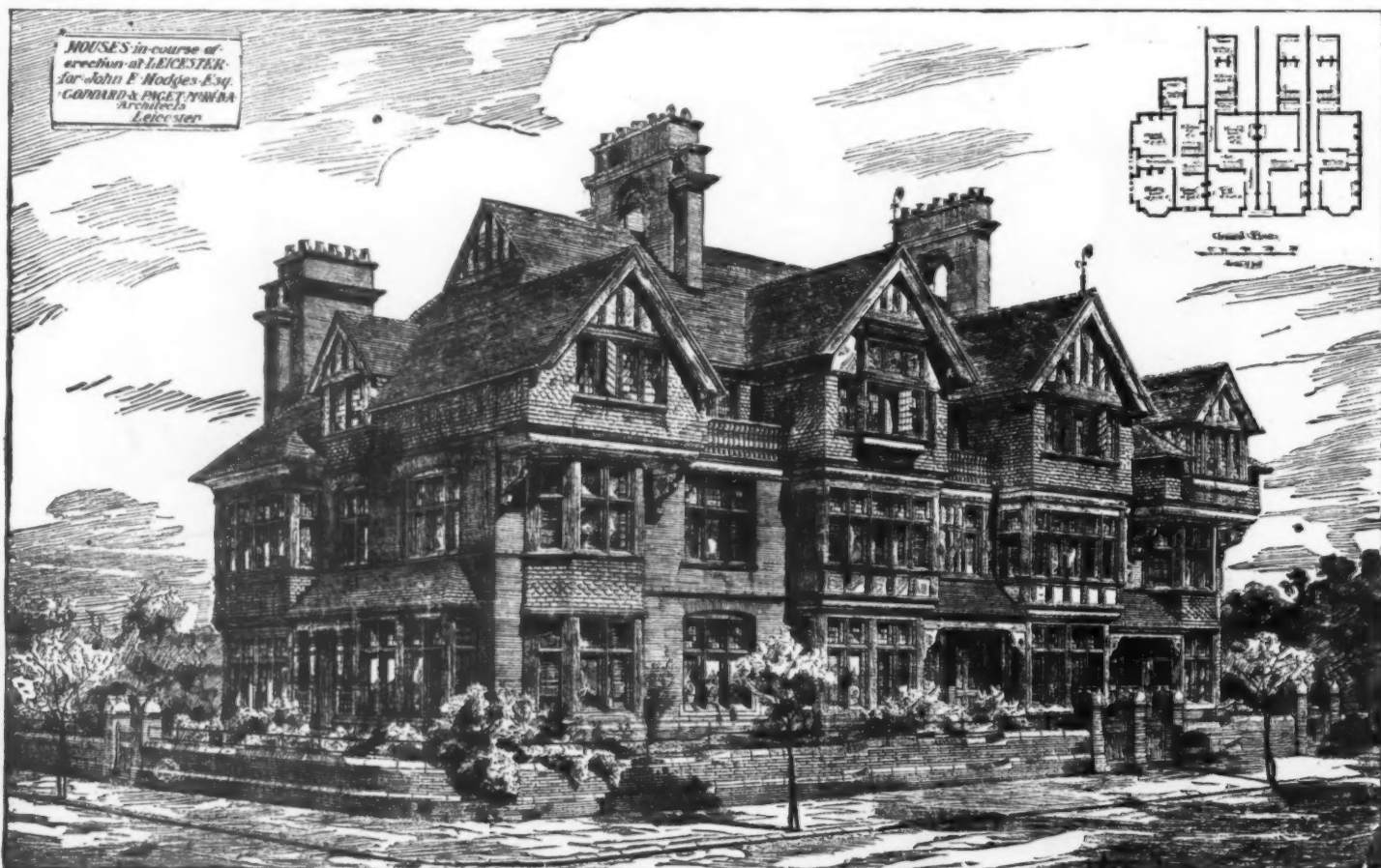
HOUSES AT LEICESTER.

The houses at Leicester, of which we give a view, are placed in the best residential part of the town, near to Vic-

noticed in this paper some months ago) has extended his investigation to twenty-two kinds of granite, twenty-three of sandstone, seven of limestone, seven of marble, three of conglomerate, one of slate, one of soapstone, and one of artificial stone. Under the application of the heat granite (1) began to yield at a temperature between 700° and 800° F.; (2) became cracked between 800° and 900° F.; (3) became generally cracked between 800° and 950° F.; and (4) was made worthless by or before reaching a temperature of 1,000° F.

The following table contains these results, and those also for the other kind of stones, the stages of destruction being indicated by the inclosed numbers:

	(1.)	(2.)
Granites.....	700° to 800°	800° to 900°
Sandstones.....	800° to 900°	850° to 1,000°
Massive limestones.....	850° to 950°	900° to 1,000°
Marbles.....	900° to 1,000°	950° to 1,000°
Conglomerates.....	600° to 700°	700° to 800°



SUGGESTIONS IN ARCHITECTURE.—HOUSES AT LEICESTER.

pounds to the square foot, and the columns of the Pantheon 60,000 pounds.

FIREWORK FORMULÆ.

COLORED LIGHTS.

These fires serve to illuminate, hence intensity of light with as little smoke as possible is aimed at. In the preparation of such mixtures the ingredients, which should be perfectly dry, must be reduced separately, by grinding in mortar or otherwise to very fine powders, and then thoroughly but carefully mixed together on sheets of paper with the hands or by means of cardboard or horn spatulas.

The mixtures are best packed in capsules or tubes about one inch in diameter and from six to twelve inches long, made of stiff writing paper. Greater regularity in burning is secured by moistening the mixtures with a little whisky and packing them firmly down in the cases by means of a wooden cylinder, then drying. To facilitate ignition a small quantity of a powder composed of meal powder 16 parts, niter 2, sulphur and charcoal each 1, loosely twisted in this paper, is inserted in the top. The tubes are best tied to sticks fastened in the ground.

WHITE LIGHTS.

Salt-peter	4 ounces.
Sulphur	1 ounce.
Black sulphide of antimony	1 "

YELLOW LIGHTS.

I.	
Chlorate of potash	4 ounces.
Sulphide of antimony	2 "
Sulphur	2 "
Oxalate of soda	1 ounce.

II.

Salt-peter	140 ounces.
Sulphur	45 "
Oxalate of soda	80 "
Lampblack	1 "

GREEN LIGHTS.

I.	
Chlorate of baryta	2 ounces.
Nitrate of baryta	3 "
Sulphur	1 ounce.

II.

Chlorate of potash	20 ounces.
Nitrate of baryta	21 "
Sulphur	11 "

RED LIGHTS.

Nitrate of strontia	25 ounces.
Chlorate of potash	15 "
Sulphur	13 "
Black sulphide of antimony	4 "
Mastic	1 ounce.

PINK LIGHTS.

Chlorate of potash	12 ounces.
Salt-peter	5 "
Milk sugar	4 "
Lycopodium	1 ounce.
Oxalate of strontia	1 "

BLUE LIGHTS.

Chlorate of potash	3 ounces.
Sulphur	1 ounce.
Ammonio-sulphate of copper	1 "

For colored fires, where the mixtures are ignited in shallow pans and maintained by additions of the powders, the compositions are somewhat different.

WHITE FIRE.

Niter	16 ounces.
Meal powder	4 "
Sulphur	8 "

YELLOW FIRE.

Niter	2 ounces.
Sulphur	4 "
Nitrate of soda	20 "
Lampblack	1 ounce.

RED FIRE.

Niter	5 ounces.
Sulphur	6 "
Nitrate of strontia	20 "
Lampblack	1 ounce.

BLUE FIRE.

Niter	8 ounces.
Sulphur	2 "
Sulphate of copper	4 "

GREEN FIRE.

Niter	24 ounces.
Sulphur	16 "
Nitrate of baryta	48 "
Lampblack	1 ounce.

BENGAL FIRE.

Sulphur	4 ounces.
Meal powder	4 "
Antimony	2 "
Lampblack	16 "

COLORED STARS FOR ROCKETS.

	White.	Yellow.	Red.	Blue.	Green.	3 points
Niter	16	—	—	—	—	—
Sulphur	8	1	—	—	—	7
Meal powder	4	—	—	—	—	10
Charcoal	—	1	—	—	—	—
Nitrate of soda	—	6	—	—	—	—
Chlorate of potash	—	—	5	8	3	—
Nitrate of strontia	—	—	20	—	—	—
Gum dammar	—	—	4	4	—	—
Sulphate of copper	—	—	—	4	—	—
Nitrate of baryta	—	—	—	—	6	—

The materials are separately reduced to fine powders, mixed with the hands, moistened with whisky containing a little gum, moulded into small lumps, and dried. A small

quantity of the following composition placed beneath the ball serves to throw it out of the tube:

Niter	3 ounces.
Sulphur	1 ounce.
Meal powder	8 ounces.
Charcoal	3 "

The tubes are usually made by winding and pasting over a half inch mandrel a dozen turns or more of heavy straw paper. One end of the tube is plugged with clay or clay and plaster, and the other primed with a quick match as described under Colored Lights.

"Flower pots" and "fountains" are usually made in a similar manner, only the diameter and capacity of the tubes are greater. These tubes should be made of metal.

ROCKET COMPOSITION.

Niter	26 ounces.
Sulphur	5½ "
Charcoal	19 "

The head of the rocket is usually charged with a number of vari-colored stars similar to those used in Roman candles. Lances are small paper cases, two to four inches in diameter, filled with composition, and are used to mark the outlines of figures. They are attached endwise to light wooden frames or sticks of bamboo and connected by streamers or quick match. The following are some of the compositions used in these:

	White.	Yellow.	Red.	Blue.	Green.
Niter	26	—	16	8	96
Sulphur	9	4	17½	2	64
Meal powder	5	4	7½	—	—
Nitrate of soda	—	16	—	—	—
Lampblack	—	2	—	—	8
Nitrate of strontia	—	—	30	—	—
Sulphate of copper	—	—	—	4	—
Nitrate of baryta	—	—	—	—	192

Sun cases are cases made like rocket tubes and filled with the following composition:

Niter	1 ounce.
Sulphur	1 "
Meal powder	16 ounces.
Charcoal	4 "

They are attached to wooden frames to give long rays of sparkling light.

COMPOSITIONS FOR PIN-WHEELS, ETC.

	Common.	Brilliant.	Chinese.	White.
Niter	6	1	1	6
Sulphur	1	1	1	7
Meal powder	16	16	7	16
Charcoal	6	—	—	—
Steel filings	—	7	—	—
Cast iron filings	—	—	7	—

Streamers or quick matches, used for communicating fire quickly from one tube to another in display pieces, are composed of the following composition packed in slender continuous paper tubes:

Niter	2 ounces.
Sulphur	1 ounce.
Meal powder	16 ounces.
Charcoal	4 "

The mixture for golden rain is composed of:

Niter	16 ounces.
Sulphur	11 "
Meal powder	4 "
Lampblack	3 "
Flowers of zinc	1 ounce.
Gum arabic	1 "

All the materials used in fireworks must be in the state of fine powders and perfectly dry.

COLORED LIGHTS IN PARLOR THEATRICALS.

A CORRESPONDENT writes:

Having occasion to assist in getting up a series of tableaux, considerable difficulty was encountered in securing a satisfactory light. Living at some distance from New York, a calcium light was difficult to procure, and, moreover, too expensive. The use of gas and reflectors had been suggested. Procuring two 14-inch glass reflectors, I experimented with gas with poor success. While the amount of light reflected was unsatisfactory, the interposition of a sheet of colored glass, or even a film of gelatine, sensibly diminished its volume.

Compelled to fall back on colored fires, I constructed a furnace of tin at small expense, that succeeded beyond expectation. A tin cylinder, 18 inches in diameter, was opened out at the side to admit a pane of glass, 16x24 inches. This glass, fastened securely in its place, constituted one side of the box, the curved inner surface of bright tin served as a reflector. A sheet iron bottom and an 8 inch heater pipe, leading from the top of the cylinder out through a convenient window into the open air, completed the apparatus. At the back of the box was constructed a sliding door large enough to freely admit the hand and closing tightly.

The peculiarity of the apparatus was:

1st. The large smoke pipe which was necessary to conduct rapidly away the large volume of smoke generated; and

2d. The box was made as nearly as possible air tight. The chlorate of potash furnished all the oxygen necessary for combustion, and all the air necessary for draught was admitted through the slide door, which could be closed quickly upon any indication of a back draught.

The following formula for red fire gave the best results:

Powdered nitrate of strontia	8 ounces.
Powdered chlorate of potash	4 "
Shellac in coarse powder	3 "
Lycopodium	¼ ounce.

This mixture burns slowly, gives a good light, contains no sulphur, and can be prepared by any druggist.

By placing the fire in tin troughs, 8 or 10 inches long, the amount of light and length of burning can be regulated to a nicety, and by alternating red, blue, and green in the same trough, these colors can be exhibited in any desired succession.

In a furnace of this description I burned colored fires for an hour without the slightest disagreeable odor being perceptible in the room.

POPULAR SCIENCE OF COLORS.

WITH SPECIAL REFERENCE TO THE MIXING, HARMONY, DISCORD, AS WELL AS THE GRADUAL AND SIMULTANEOUS CONTRASTING OF COLORS.

By JOHANNES HIRRLINGER, a Water-color Artist of Stuttgart.

ONE of the most important means of producing effects in nature, art, or industry is by the use of color, and nowhere, in its employment, do we find less uncertainty than in the industrial field. To meet this, and remove it, as far as possible, is the object of these papers, which, in a simple and comprehensible manner will endeavor to satisfy the practical requirements. It is to be understood that, in the colors which we are about to consider, reference is made to those which are known technically as coloring matters and not to the colors of the spectrum, otherwise such a misconception might easily lead to erroneous impressions. Bearing this in mind, we will now proceed to the consideration of the "mixing of colors," upon which depends all that subsequently follows.

I—MIXING OF COLORS.

When we speak of mixing colors, the mind naturally wanders to the common method of combining the pigments in the crude ground state, but there are, in addition, other methods of mixing which it will be essential to describe. However, we will treat of the first-mentioned method.

All colors which are used in aquarelle painting consist of three primary fundamental colors, viz., red, yellow, and blue. From these an expert mixer of colors should be competent to produce all possible shades and tints.

The substances which serve as a basis for the coloring materials are carmine, gamboge, and Prussian blue.

When carmine is mixed with gamboge, orange is obtained; gamboge and Prussian blue produce green; and from Prussian blue and carmine, violet results.

From the term orange, green, violet, is meant to be conveyed the idea of a tint composed of equal amounts of the primary colors—that is to say, middle tints which, of course, can be varied at will by increasing or diminishing the amount of any of the original primary colors in the mixture, thus—

Orange.—Two parts of carmine and one part of gamboge give a red orange; two parts of gamboge and one of carmine produce a yellow orange.

Green.—From two parts of gamboge and one Prussian blue, a yellow green is obtained, and a blue green from two of Prussian blue and one of gamboge.

Violet.—Two parts of Prussian blue combined with one of carmine produce a blue violet, while two of carmine to one of Prussian blue give a red violet.

From the above mixtures, including the primary colors, it will be seen that we have twelve different shades, viz., red, red orange, orange, yellow orange, yellow, yellow green, green, blue green, blue, blue violet, violet, and red violet.

If now, we change the above proportions, which were two to one, and take three to one, we obtain nine additional tints, making in all some twenty-one shades. In addition, if we add to each of these saturated colors a larger or a smaller amount of pure water, by which lighter or darker tints are produced, we shall have for each color, by limiting ourselves to five degrees of dilution, not less than one hundred and five different shades.

Besides the above colors, each of which is composed of two primary colors, we obtain all the varieties of gray and brown shades, which consist of three colors, and can be produced by this mixing.

BROWN PIGMENTS.

Red Brown.—A beautiful red brown is produced by combining three parts of carmine, two of gamboge, and one of Prussian blue.

Yellow Brown is made by taking three parts of gamboge, two parts of carmine, and one of Prussian blue.

Dark Brown or Black.—This pigment is made by mixing together about three parts of Prussian blue with two parts each of gamboge and carmine. It is not easy to give more definite proportion for this color, as it depends chiefly upon the taste of the artist as to which shade of brown is most desirable, that is, whether it is to be bluish-red or yellowish. Also, it must be borne in mind, that Prussian blue possesses greater coloring power than either carmine or gamboge, and hence blue is apt to predominate when too much of that base is used. At all events, the proportions given for the brown pigment are not to be accepted as absolute, for the formulae are only intended to give an approximate idea of those colors which are to be used in excess in the mixture. It remains with the artist to combine the primary colors, and mix them until the desired tint is obtained.

Terra sienna, red ochre, sepia, and all brown colors which are found in nature or are obtained artificially by chemical means, may readily be produced by properly mixing the primary colors. In practice, the employment of the natural colors or the preparation by mixture of the primary colors, is, of course, at the option of the artist.

GRAY PIGMENTS.

Concerning the mixture of gray pigments there is very little to be said. They depend essentially upon the principles that have just been given relative to the brown colors. Likewise, in this case, the blue is as predominating as in the latter, and if the dark brown or black were to be diluted with water and thinly spread out, it would be nothing but gray. The mixing of gray is but slightly employed in aquarelle painting, for it is simpler to use India ink, Frankfort black, neutral tint, or the like, sufficiently diluted. In painting with opaque colors, the case is different, for then gray is produced by mixing black and white, and each is made lighter according as it is mixed with white.

Another method of mixing is by overlaying, which is also employed in aquarelle painting. By this means the colors appear more brilliant than when they are mixed on the palette. When gamboge is brought into a surface already colored with carmine, orange is produced; green results when gamboge is laid over Prussian blue, which produces violet when placed in carmine. In this method, as well as in the previous method of mixing, the production of a large number of tints at will depends on the strength of the tint used in the primary color.

For it is by no manner of means the same, whether one uses dark yellow on light red, or light yellow on light red, or light yellow on dark, or dark yellow on dark red, to produce orange, each one of these four variations will produce a different shade of orange. The same is true for the green and the blue.

For any one that is interested in this matter, a demonstration picture of mixing may easily be produced in the follow-

ing manner: A circle is drawn with India ink on paper, and divided into twelve sectors, which are numbered from above toward the left, 1, 2, 3, etc., to 12. (The upper middle sector, 1, therefore has as its left sector 2, and as its right sector 12.) The sectors 1, 2, 3, 4, 10, 11, and 12 are now tinted uniformly with carmine thinned to a light pink. After the sectors 6, 7, 8, 9, 10, 11, and 12 (after being dried) are tinted with thinned Prussian blue. Then the sectors 2, 3, 4, 5, 6, 7, and 8 are coated with thinned gamboge. When all the colors have entirely dried, the disk is completed as follows: The three colors just employed are darkened one shade by adding on the palette or in the dishes, and then covering the following sectors for a second time: with red, 3, 2, 1, 12, and 11; with blue, 7, 8, 9, 10, and 11; with yellow, 3, 4, 5, 6, and 7. Again the colors are darkened one shade, and the following sectors are coated for a third time: with red, 3, 1, 12; with blue, 8, 9, 10; with yellow, 4, 5, 6. Once more the colors are made darker by one shade and applied for the fourth time on the following sectors: with red, 1; with blue, 9; with yellow, 5. The circle is now completed, and it is composed of a series (like a rainbow) of the previously mentioned colors of the spectrum, *i. e.*, red, red orange, orange, orange yellow, yellow, yellow green, green, green blue, blue, blue violet, violet, violet red. It is due to this overlaying of the three primary colors in lighter and darker tints, that, for instance, the orange red sector which touches the carmine, was colored once by the lighter yellow and three times by the stronger carmine, which is equal to a mixture of two parts of carmine and one of gamboge. The yellow orange adjoining the gamboge is produced by one layer of the lightest carmine and three layers of the darkest gamboge, which is equal to two parts of gamboge and one part of carmine. The intermediate orange was produced from two layers each of carmine and gamboge, equivalent to an orange formed from equal parts of carmine and gamboge. The yellow green adjoining the gamboge was coated once with blue and three times with yellow. The blue green received one coat of light yellow and three of blue. The intermediate green was twice overlaid with yellow and twice with blue. The blue violet was covered once with red and twice with blue; red violet once with blue and three times with red, etc., etc.

If, now, four such circles be drawn, one to the right and one to the left, one above and one below, in such a manner that they all intersect each other at the center, and if they are all colored in the previously described manner with the three primary colors, we shall have, in addition to the twelve mentioned colors of the spectrum, a number of broken and all kinds of brown and gray tints. These latter are produced by overlaying all of the three primary colors at the points of intersection of the four circles, *i. e.*, the violet sectors of one circle overlap the yellow, green, and orange sectors of the other circles, etc. Another method of mixing colors is by placing small portions of color side by side on a colored ground. For instance, light yellow stripes on a blue ground produce a green effect.

Red stripes on a yellow ground make the surface appear orange, etc. The mixture, in this case, does not take place on the body itself, but is produced in our eyes, from the two kinds of light striking the organ simultaneously.

II.—HARMONY OF COLORS.

By harmony of colors we understand colors placed side by side in such a manner that they do not injure the effect of each other, rather on the contrary, complete each other, *i. e.*, they gain in intensity.

Those who are familiar with the harmony of colors can, by using objects of familiar use, make such selections in fitting up apartments, in dressing, etc., so that with the greatest simplicity they are able to produce a more favorable effect than is possible with the most extravagant expenditures, without a sense of harmony in color.

A merchant, dealing in colored goods, can very greatly improve the appearance of his stock by knowing how to group them in such a way as to produce a harmonious effect. Very often, owing to a lack of taste with reference to colors among dealers, it will be found that the silks in one store will appear much fresher and brighter than in another. This difference in effect of the colors is, however, nothing more or less than that one merchant arranges his goods so that the colors are in harmony, while the other does not follow any definite plan. In the first instance the goods gain, while in the second they lose in intensity of color. The attention of the ladies is particularly called to the importance of harmony in colors, for, most of them, in the selection of their colored dresses, bonnets, and trimmings, produce the greatest discord in the composition of the colors. Harmony in color does not depend on the will or caprice or personal taste of an individual, but it is based on the unchangeable laws of nature, which we shall immediately discuss.

Red and Green.—A red body reflects green rays, while on the other hand, a green body reflects red rays. Therefore green is the color which completes red, and similarly red is the color which completes green. Both colors, therefore, gain in intensity.

Blue and Orange.—A blue body often reflects orange rays, and inversely an orange body will frequently reflect the blue rays. Orange is, therefore, the complementary color of blue and *vice versa*, therefore each color intensifies the other.

Violet and Greenish Yellow.—A violet body reflects greenish yellow, and inversely a greenish yellow body reflects violet. Both colors, therefore, complete each other and intensify each other.

Indigo and Yellow.—Indigo reflects yellow, and yellow indigo rays, hence they are complementary and intensify each other.

It would carry us too far to describe all the other colors which are complementary; therefore, for further study, reference should be made to the previously described circle of colors.

All spectral colors (not to be mistaken for the brown tones in the center) are complementary, that is, the two colors lying opposite each color; for instance, the upper carmine and the intermediate green.

III.—DISCORD OF COLORS.

A. Two Simple Colors.—**Red and Yellow.**—Red appears darker purple, because the indigo rays are imparted to it from the yellow; yellow appears greenish, because green rays are imparted to it from the red.

Yellow and Blue.—Yellow takes away the orange rays from the blue, and appears reddish; blue absorbs the indigo rays from the yellow, and appears darker.

Blue and Red.—Blue appears greenish from the effects of the green rays of the red; red, on the contrary, from the orange rays of the blue, appears yellowish.

B. A compound color and a primary color, the latter being contained in the former:

Red and Orange.—Red absorbs the blue rays from the orange and appears bluish, violet; orange is influenced by the green rays of the red and appears yellowish, *i. e.*, lighter.

Red and Violet.—Red beside violet appears yellower, because it receives the yellow rays from the latter; violet appears darker, more dusky, because greenish rays are absorbed by it.

Orange and Yellow.—Orange loses from its yellow and appears redder; the yellow appears more greenish.

Green and Yellow.—Green loses its yellow and appears darker, more blue; the yellow is influenced by the reddish rays of the green, and it appears reddish, *i. e.*, orange.

Green and Blue.—The green appears lighter, more yellow, as if it were faded; the blue appears reddish alongside of the blue, *i. e.*, like violet.

Violet and Blue.—The violet loses its blue and assumes a reddish appearance in comparison with the blue, that is, greenish.

C. Two compound colors which have one primary color in common.

Orange and Green.—Both colors contain rays of yellow and each loses some of its tint by contact; the orange appearing more red, and green more blue.

Green and Violet.—Both of these colors have blue in common, and hence by contact each loses in appearance; the green becoming more blue, and the violet more red.

Violet and Orange.—These two colors have the red rays in common, which is lessened by contact; the violet becoming more blue, while the orange appears more yellowish.

IV.—PHENOMENA OF GRADUAL CONTRAST.

It has been stated in the two previous chapters relating to the harmony and discord of colors, that red reflects green rays and the green reflects the red rays, that all colors have their complementing or complementary shades, which may be observed by the eye. This statement will be confirmed in the following:

If one fixes his eyes for some time on a red object and then quickly looks away or closes the eye, it appears just if the same object appeared before him in green. Similarly a green object, when stared at, produces a red effect when the eye looks away. When one looks at a blue object for some time, there is produced in the eye the sensation as if one saw an orange object, and contrariwise, an orange colored object appears as if it were blue.

When these colors are seen singly, as for instance in the form of flowers or some other ornamentation on a light gray background, and closely watched for some time, it will be found that after a while the gray ground will appear slightly tinged by the complementary color. In the same way with:

Red, the gray ground is tinged	greenish.
Green, do.	reddish.
Blue, do.	orange.
Orange, do.	bluish.
Violet, do.	yellowish.

With wall-papers and woven fabrics these facts have often been noticed and even have led to serious disputes. Thus, for instance, at Paris, in a factory of wall-papers, a case occurred in which a color mixer was found fault with for having used greenish gray instead of an ash gray as a back-ground for a pattern of red flowers and garlands. His justification, however, was at hand, in the shape of a remnant of the gray pigment, which, when examined by itself, was in reality of ash gray tint. It was Chevreul, the distinguished chemist and director of the Gobelins Manufactory at Paris, who related the previous case, and the difficulty was settled by his showing that the red flowers imparted the greenish tint to the gray ground. A similar circumstance occurred to a weaver. He was given some black and blue yarn, by a dealer, from which he was to produce a blue and black checkered cloth. When the goods were given to the merchant, he saw that the black was not so intense as the sample, and immediately charged the innocent weaver with having fraudulently substituted his beautiful black with a faded one. The weaver was on the point of being punished by the law, when Chevreul, in his expert testimony on the matter, clearly showed that the blue portions of the fabric reflected sufficient of the yellow rays to make the black appear brownish. Hence it is shown by experience that in such cases, as with the manufacturer of wall-paper, the gray ground of the paper should contain some of the color which is to be used for the design which is to be placed on the same, in order to satisfy the complementary color.

If, in the case of the Parisian wall-paper, just mentioned, some red had been mixed with the gray, the ground would not have appeared greenish, and also, if the black yarn in the case of the weaver had been dyed a little more blue, the orange rays from the blue yarn would not have shown so much on the black.

Another interesting case of deception by the gradual contrast of colors is the following: A lady desiring to purchase some silk ribbons, and being undecided as to which shade to select, had samples of blue, violet, and green shown her at the same time. After a close examination of the blue ribbon, she turned to look at the violet, to her astonishment it was not violet, but brown. Perfectly correct, from looking at the blue ribbons, the complementary color of the blue—orange—was found in her eye and was imparted to the violet, giving it the appearance of brown. From the violet ribbon, she proceeded to examine the green, sample. Here she was again deceived, for, from previously looking at the violet, light yellow was imparted to the green and it had the appearance of being faded. If, after her examination of the blue ribbon, the lady had turned to an orange colored object, her eye would have been refreshed and in fit condition to look at the violet. After finishing with the violet ribbons she should have looked at something light yellow, and then her eye would have been sensitive to the green. Therefore, dealers should take pains to always show goods on papers of the complementary colors, *i. e.*, red materials on green paper, etc.

All observations on gradual contrast, according to Pater Scherffer's explanation, produce the following result:

That in the first part of the observation of a color, a portion of the cornea of the eye becomes affected and tired by it, and that this tired portion, during the second part of the time (*i. e.*, the time of rest), perceives the complementary color.

V.—PHENOMENA OF SIMULTANEOUS CONTRAST.

If purple (red-purple red) is placed beside a brilliant carmine, the first appears darker, less bright, while the latter on the contrary becomes brighter, more fiery, almost like vermilion; if, however, the same carmine is placed beside vermilion, the carmine appears darker, that is, less bright;

so that in one case the carmine appears fiery like vermilion, while in the other it appears darker, purple.

The same takes place with vermilion, it appears alongside of the carmine much lighter, almost orange, puce colored, but when brought in contact with orange puce it appears darker, carminish. Orange puce which, alongside of vermilion, appears yellowish, when in contact with yellow shows reddish. Yellow in contact with orange puce appears yellowish green, and in contact with yellowish green it appears orange. Yellowish green alongside of yellow seems darker, *i. e.*, blue, and in contact with blue-green, lighter, that is, more yellow. Blue green in contact with yellowish green looks almost blue, and in contact with blue, yellow green. Blue appears violet in contact with blue-green, and blue green when in contact with violet.

An additional example of similar contrast is shown in the following: When light gray and dark gray are brought in contact, the former appears lighter and the latter darker than they are in reality. Any one can try this by a simple experiment. Take two strips of light gray and two strips of dark gray paper, and paste one light gray strip in contact with one dark strip, and then compare them from a short distance. It will soon be found that the light gray strip which is in contact with the dark gray appears much lighter than its isolated companion, while the dark gray seems darker, so that, therefore, the gray surfaces appear lighter and darker than in reality. A strong contrast is always noticeable between black and white. A black object on a white ground will appear much larger than it is in reality. For instance, a white stripe on a black surface seems broader than a black stripe on a white surface, although both be of the same width. The phenomena of simultaneous contrast, according to Pater Scherffer, may be physiologically explained as follows:

When one of our senses receives a double sensation, one of which is active and strong, while the other is weak, it will be found that the latter is not felt. This must be particularly the case when both impressions are of the same kind, or when a strong effect from an object on one of our senses is followed by another of the same kind which is milder and weaker.—*Neuere Erfindungen und Erfahrungen*, vii., pp. 433 and 438.

WATERPROOFING CLOTH.

WITHOUT considering the processes by which cloth is waterproofed with such substances as India-rubber, oils, wax, and varnishes, there are several processes in practical use by which cloth is rendered non-absorbent of water—and for all practical purposes waterproof—without materially affecting its color or appearance, greatly increasing its weight, or rendering it entirely airtight. These processes depend mainly upon the reaction between two or more substances, in consequence of which a substance insoluble in water is deposited in the fibers of the cloth.

The following are several of these processes:

LOWRY'S PROCESS.

Soap.....	2 ounces.
Glue.....	4 "
Water.....	1 gallon.

Soften the glue in cold water and dissolve it together with the soap in the water by aid of heat and agitation.

The cloth is filled with this solution by boiling it in the liquid for several hours, the time required depending upon the kind of fiber and thickness of the cloth. When properly saturated the excess of liquid is wrung out and the cloth exposed to the air until nearly dry; then digested for from five to twelve hours in the following solution:

Alum.....	13 ounces.
Salt.....	15 "
Water.....	1 gallon.

It is finally wrung out, rinsed in clean water, and dried at a temperature of about 80° Fah.

Paul's process requires a small quantity of oil, but in other respects resembles the last. It is given as follows:

Sodium carbonate (com'l).....	1 pound.
Caustic lime.....	1/2 "
Water.....	2 1/2 pints.

Boil together, let it stand to settle, then draw off the clear lye, and add to it—

Tallow.....	1 pound,
Resin.....	1/2 "

previously melted together. Boil and stir occasionally for half an hour, then introduce—

Glue (previously softened).....	3 ounces,
Linseed oil.....	3 "

and continue the boiling and stirring for another half hour.

In waterproofing one half ounce of this soap is mixed with a gallon of hot water, and in this the goods are soaked for about twenty-four hours, according to thickness and character. The pieces are then allowed to drain until partly dried, then soaked for six hours or more in a solution prepared as follows:

Aluminum sulphate.....	1 pound.
Lead acetate.....	1/2 "
Water.....	8 gallons.

Shake together, allow to settle, and draw off the clear liquid.

Wring out after rinsing, and dry at a temperature of 80° Fah.

Blennaux uses, instead of glue and oil, as above, the gelatinous portion of sea-wrack grass with a small quantity of a drying oil and common resin soda soap.

In Reimann's process the cloth is passed slowly by machinery through a tank divided into three compartments, the first containing a warm solution of alum, the second a warm solution of lead acetate, and the third pure water, which is constantly renewed. The cloth on passing from the latter is brushed and beaten to remove the salt adhering to the surface, and finally hot pressed and brushed. In this case lead sulphate is deposited in the fibers.

In Townsend's process two solutions are used as follows:

British gum.....	20 pounds.
Soap, white.....	10 "
Water.....	16 gallons.

The solution is boiled for some minutes, and if color is required one pint of logwood liquor is added. The second solution consists of a saturated solution of alum in water, or—

Zinc sulphate.....	6 pounds.
Water.....	9 gallons.

Bullard's process is somewhat similar to Reimann's. In this strong aqueous solutions of sulphate of aluminum and lead acetate are used alternately.

Berlin waterproof cloth is said to be prepared by saturating the cloth in a solution of acetate of aluminum and copper, then dipping it successively in water glass and resin soap.

PSEUDO-CERAMICS.

The ceramic art is generally practiced under conditions which render it exceedingly difficult for an amateur to make progress in it, even so far as to produce work of the most modest and unassuming character.



FIG. 1.

In the first place it is difficult to obtain the proper quality of clay, unless one is in the vicinity of a pottery or clay bed; in the second place, even though one has the skill and practice which will enable him to shape the clay into the desired forms, still it is difficult, if not impossible, to bake the work after it is done in other respects, and it can scarcely be expected that a potter will bake these odd articles. These and other difficulties prevent the would-be amateur potter from attempting what, under more favorable circumstances, might be productive of works creditable to both the art and the artisan.



FIG. 2.

Late years some exceedingly plain articles of pottery, with extremely simple ornamentation, consisting merely of a little paint and a little glaze, have become very fashionable, and have been accepted as works of art. Some of these articles are handsome, others are not. Inasmuch as these articles have no practical utility, they do not require to be made of materials either fireproof or waterproof. The requisites are simply shape, strength, and a resemblance to pottery.

The materials required for making imitation pottery are junk-board—a strong thick board having a smooth surface—



FIG. 3.

glue, and small wire nails. The ornamentation may consist of such floral or picturesque decorations as the maker is able to produce if he or she be artist enough to paint in oil colors. Without this ability the aid of chromos must be invoked. This will certainly afford very satisfactory results, and the expense will be slight, as very passable German chromos may be obtained for twenty-five cents each. The

engravings show several examples of pseudo-ceramics which are designed with reference to the material to be employed, and compare favorably with the high-priced articles to be found in the shops.

The body of the vase shown in Fig. 1 consists of rectangular pieces of junk-board nailed and glued together at the corners, after the fashion of an ordinary wooden box. The nails used are the small wire nails used in bracket-work. They are about three-eighths of an inch long, and about the size of an ordinary pin. In the absence of such nails common pins may be cut off and used to good advantage.

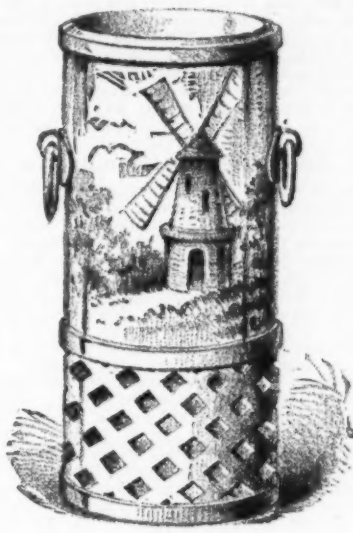


FIG. 4.

Holes for these nails must be made with a fine-pointed awl. The bottom of the vase consists of a single piece of junk-board, with V shaped notches cut from the corners to give it the bevel.

The concave sides of the top consist of sections of paper tube such as is employed for mailing pictures. The head around the top is of wood. Any imperfections in the joints may be filled with a mixture of glue size and whiting formed into a putty.

Fig. 2 shows a vase which can be readily made after the above hints. It is triangular in form, and has three wooden balls for legs. The band around the top is merely a narrow strip of pasteboard glued on.



FIG. 6.

Fig. 3 shows a cylindrical vase made of a strip of junk-board scarfed or beveled on the edges and lapped and glued. To facilitate bending the junk-board, the side which is to be outermost in the vase is wet. The bottom is glued and nailed in, and the corners are rounded with a moderately coarse file and sandpaper. A band of pasteboard finishes the top, and three or four wooden balls form the legs. The inner corner of this vase at the bottom may be filled in slightly with glue and whiting to strengthen it.

The vase shown in Fig. 4 is made in the same way as that

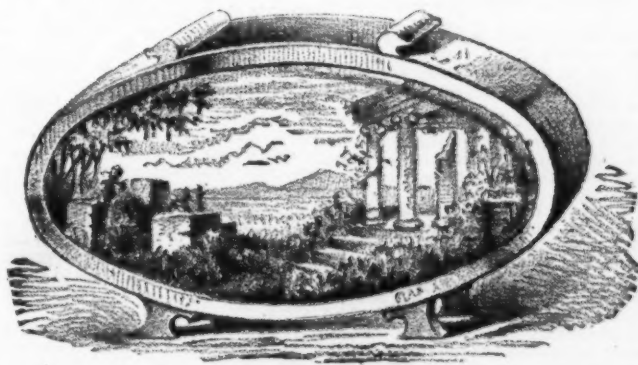


FIG. 7.

last described. The bottom is placed above the lattice work. The latter is formed by cutting out the holes with a chisel. The ring and its fixture are made of wood.

Figs. 5, 6, and 7 are examples of "pilgrim vases" of different shapes. That shown in Fig. 5 is circular and has convex sides or heads. The hoop is bent in the manner already described, i. e., after first wetting the outer side.

The heads are made convex by wetting the junk-board and hammering it in the middle, in the same way that a shoe-maker hammers a shoe sole, or top, to make it convex, that is, it is placed upon an ordinary flat iron and hammered with a round-faced hammer until it acquires the desired convexity. The sides are nailed and glued to the hoop, and a thin pasteboard circle is glued to each of the convex surfaces of the vase to form a border. The mouth of the vase is made of four pieces of junk-board, glued and nailed together and secured to the vase by glue. The legs of this vase consist of two pieces of paper tube closed at the ends with turned pieces of wood. The corners of the vase may be filed and sandpapered to make it ready for further operations.

After what has already been said the construction of the vases shown in Figs. 6 and 7 will need no description, except



FIG. 5.

that the vase shown in Fig. 7 has wooden legs, and wooden strips at the sides of the mouth.

The body of the vase shown in Fig. 8 can be constructed without special description. The ornamentation consists of ordinary artificial flowers and vines, secured to the body of the vase with common glue. They are stiffened by spraying or spattering shellac varnish on them from an old tooth or nail brush. They should be sprayed several times to give them a good heavy coating of varnish. When this becomes dry the leaves and flowers may be painted in the same manner as the other parts of the vase. These vases should be smoothly finished and thoroughly dried before any attempt at finishing should be made. The first operation in

the way of finishing is to give the vase two coats of shellac varnish inside and out, allowing one coat to become dry before the other is applied. When both coats of varnish are dry and hard, which will require about two days, the painting may be done.

It is not the design of this article to enter into all of the details of painting necessary to enable the tyro to paint landscapes or flowers, but a suggestion or two in regard to the painting will not be out of place. The best results will be obtained by giving the vase two coats of white paint before

attempting to lay on the color. The sides and border of the vase should be of a neutral tint, slightly mottled. An olive green or a gray looks well and gives relief to any design that may be chosen.

No attempt should be made to apply the colors smoothly. The whole should be done in a bold dashing way.

If painting is out of the question, some of the chromos

before-mentioned may be used with good effect. The edges of the chromos may be concealed beneath the pasteboard border.

In either case after the paint on the article has become thoroughly dry and hard, which will probably require four or six weeks, it may receive a coat of pottery varnish to be obtained at any of the color stores.



FIG. 8.

In the case of the applied artificial flowers, they should be heavily painted with, say, four or five coats of white paint before applying the color.

Ornamental articles of this kind cost little save the labor, and pass readily for the real article.

MOTHER-OF-PEARL AND PEARL INLAYING.

MOTHER-of-pearl is chiefly obtained from the pearl oyster (*Meleagrina margaritifera*) which is found in the Gulf of California, at Panama, Cubagua, Ceylon, Madagascar, Swan River, Manila, and the Society Islands. The black-lipped shells from Manila are most highly prized. The Society Islands furnish the silver-lipped sort, and Panama the "bullock" shells.

The genera *Haliotis*, *turbo*, etc., also furnish some mother-of-pearl. Technically the mother-of-pearl obtained from the pearl oyster is known as white pearl; that of *Haliotis* or sea-ear as aurora or ear shell; it is easily distinguished from the former by its prismatic colors and wrinkled appearance.

The peculiar and varied tints exhibited by mother-of-pearl is due to the structure of its surface, which, owing to the great multitude of minute grooves upon it—often many thousands to the inch—decompose the light which falls upon it and reflect different hues.

The pearl shell is lamellar in structure, and admits of being split into laminae, but this method of dividing it is seldom resorted to owing to the liability of spoiling the shell.

In working up mother-of-pearl the saw, file, and grindstone are the principal tools employed. A shell is selected with a coating of the substance of a thickness as nearly as possible to suit the required purpose. Square or angular pieces are cut out with a small circular or buck or fret saw to suit convenience, the piece being held and manipulated with the hand or clamped in a vise. Buttons and such circular pieces are cut with an annular or crown saw fixed upon a mandrel. All such tools used in cutting pearl must be kept well moistened with water to prevent overheating. The pieces are usually dressed upon a grindstone, the edge and face of which are grooved or ridged to prevent clogging. The stone is kept wet when in use; for this purpose weak soapuds is better than water alone.

When the pieces have been properly shaped on the stone they are dressed with pumice stone and water. In some cases the better plan is to have the piece of pumice stone shaped so as to adapt it to the form required and held in a vise while the work, held in a clamp, is revolved in contact with it on the lathe. After the application of the stone fine powdered pumice stone, free from coarse grit, is applied with a cork or cloth moistened with water. In the final polishing rotten-stone is employed. This is moistened with dilute sulphuric acid (1 acid, 15 water) and applied with a cork. The acid is said to develop finely the striated structure of the shell. In some works it is thought necessary to use emery before the rotten-stone, and to use a limpid oil in place of the acid.

Knife and razor handles of pearl, after having been roughed out, are drilled where the rivets are to be inserted, lightly riveted together, shaped on the stone, and finished as above described, the last finishing touch often being done by friction of the hand of the workman.

In some shops much of the polishing is done on cloth-covered wheels, the moist cloth carrying the polishing materials. Separate wheels are used for the different materials. For some common work powdered chalk or Spanish whiting is used in place of rotten-stone.

Pearl is etched by a process very similar to that used in etching copper. The designs or patterns are drawn upon it with asphaltum varnish, and all parts not intended to be etched having been similarly protected, the piece is submitted to the action of nitric acid. When the parts unprotected have been sufficiently eaten away by the acid the piece is rinsed in cold water and the varnish washed off with a little turpentine or benzine.

Thin pieces of mother-of-pearl of a like pattern are usually gang-cut; that is, the thin plates are glued together, then held in a clamp and cut, drilled, and dressed as one piece, after which they are separated by being thrown into hot water, which separates the glue.

In common pearl-inlaid work, films or very thin pieces of mother-of-pearl are connected to a background, usually of papier maché or iron, by japan varnish. The plate having been cleaned and dried receives a coat of the varnish, and when this is nearly dry the pieces of pearl, cut out with a scissors by the artist to represent leaves or designs, are pressed against and adhere to the varnish. The plate is then

put in the japanner's oven until the coating becomes hard. A second coating of varnish is then put on—indiscriminately over the pearl and all—and when this has been dried or hardened in the oven the portions adhering to the pearl pieces is removed with a knife blade, and the whole surface is rubbed smooth with pumice stone and water. With the aid of a little gold size, gold leaf, and color, and camel's hair brush the artist then develops the design, the beauty of which depends of course upon his skill. Finally the article receives a coat of clear spirit varnish.

Besides the white and aurora shell referred to above, the glistening green snail shell is very frequently used. Its tints are light and dark green, yellow, and pink, blended. The varnished surface is sometimes ornamented with transferred drawings or engravings. When the varnish is nearly dry the engraving is spread out, face downward, upon it and carefully pressed so as to exclude air bubbles. After the varnish is thoroughly dry the paper is well moistened with warm water by means of a sponge. It may then be rubbed off, the lines of the print remaining adhering to the varnish.

ABOUT PHOTO-LITHOGRAPHY.

THE whole process of photo-lithography bids fair to be revolutionized by the introduction of the velvet roller, an innovation we owe, as already mentioned in these columns, to the Austrian Geographical Institute in Vienna. Several establishments, both private and government undertakings, have already adopted the new form of roller, and Major Waterhouse, B.S.C., the Deputy-Surveyor-General of India, was so pleased with its working, that he suggested some experiments with rollers made up with other similar materials. Of these experiments, as also of the velvet roller in general, it is our intention to say a few words.

But, first of all, on the subject of photo-lithography generally, we must utter a word of warning. Only those who are competent lithographers can succeed in photo-lithography. And, indeed, this is only to be expected. Lithography is of itself a delicate art, and photo-lithography is more delicate still. A lithographer has already much to learn when he begins, so that he who knows nothing of that art had best leave photo-lithography alone. Only when he has a competent lithographer to assist him should a photographer engage in the art of photo-lithography.

But in these circumstances, he will find that with the assistance of the velvet roller he will rapidly go ahead. The treatment of the sensitized paper we need not here describe in detail, since the reader cannot do better than refer back to Mr. Butter's paper on the subject published in the *News* of March 19, 1880. Suffice it to say that the paper chosen must be good bank-post, without any ribs—since ribbed paper is not smooth and tough—and that there must be no alum put into the bichromated gelatine bath, upon which this paper is floated. Alum makes the surface hard, and with the velvet roller this may be as delicate as possible without sustaining injury.

We will suppose the bank-post paper floated upon the bichromated gelatine, and dried. It is put under a line negative—nothing is better for intensifying than the lead formula of Eder and Toth—and printed. The lines of the design can be seen upon the yellow print if you look for them, and they become yet more visible when the impression is put into cold water. It remains immersed for four or five minutes, and is then laid carefully and flat upon a glass plate, which must be a little shorter than the print. Excess of moisture is removed by means of blotting-paper, and the print is now carried off to the lithographic room.

The photographer puts the print down in front of him, upon a press or other convenient position for rolling. A stone slab about the size of the glass plate is convenient for resting the print on. The edge of the print nearest him he tucks under the glass plate; the end away from him is loose, so that when it comes to the rolling, by always rolling away from him, he presses the print down, while it yet has a tendency to flatten out and not cockle. Drawing back the roller under these circumstances would, of course, be fatal.

The velvet roller charged with ink is taken in hand and lightly passed over the print. The rolling is only done one way—away from the printer, as we have explained. The roller is but half the weight of an ordinary litho-roller, and—no pressure or scarcely any—is exerted by the printer. It is hardly like inking a lithographic surface. The moisture over the surface of the impression repels the ink, it is true, but the lines of the drawing or design stand up so prominently that they remind one almost of relief printing. The delicacy of the lines as they gradually take up the black ink reminds one of bank-note engraving, they are so exquisitely sharp and fine, and the lithographer who for the first time undertakes the work is fairly charmed with its beauty. He scarcely knows how he has produced such exquisite work.

There must not be too much ink applied to the print, for the simple reason that this will subsequently be pressed out of shape by the lithographic press, and then the lines get blurred and ragged. A skillful photo-lithographer requires to pass the velvet roller but half-a-dozen times over a gelatine impression—supposing this has been properly exposed—to produce a perfect print or transfer.

The ink used has been transfer ink, so that nothing now remains but to go on with the lithographic work. A polished litho-stone is warmed, the inked-up print is laid face downward upon it, and then passed through the press. The result is, of course, that the inked impression is transferred to stone, and thence, of course, any number of impressions may be pulled in the ordinary fashion.

To come back to the velvet roller. It needs very careful construction, if it is to answer well. In the first place, it must be light. Velvet stretched and sewn like leather over an ordinary wooden roller will not answer. There must be either less wood, or the velvet, as Major Waterhouse prefers, may be fitted to a tin stock. In any case, the roller should not be more than half the ordinary weight. Nor must the velvet be sewn in the usual way with a double thickness at the join, but carefully drawn together with stitches. If there is a join, then the roller fails to gripe at this part, and the print at this spot not only lacks ink, but is frequently uneven.

Next to lightness, the roller should be of soft consistence, or "pudding," to use an expressive phrase of a photo-lithographer friend. To insure this, there should be a flannel under-cover, no less than three rolls of thick flannel, or so-called collar-cloth, being put round the wood or tin stock. The velvet itself soon becomes incorporated in the "pudding" mass, and especially if it happens to be cotton velvet or velveteen. And here we may mention that the result of experiments with Major Waterhouse's three rollers was to the effect that their value is in the following order, viz:

1. Cotton velvet.
2. Silk velvet.
3. Mole skin.

A "pudding" nature and "pulling power," when rolling, are the requirements of the velvet roller, and these are best secured by cotton velvet with the underfolds we have specified. The gelatine impression, during the rolling, is treated precisely as a lithographic stone, and may be wetted with sponge or rag, as occasion requires.

Of course it is impossible to scrape the ink from a velvet roller. The best way to preserve the roller is to put it into a bag after use, without any further manipulation whatever; then, before beginning work again, free the roller from the old ink by rolling it on a clean slab, cleaning the slab at intervals with turpentine of the old ink. The velvet roller should always be cleaned in this way before using.

There is one more important point, and that is the mixing of the transfer ink for application to the slab and to the roller. So that these instructions may be as practical as possible, we append here the directions of a practical photo-lithographer on the subject:

Take two ounces of transfer ink from the pot, add quarter ounce of olive oil, mix well together with the muller on a slab; this you will find gives a paste about the consistency of butter. Such paste makes capital stock. When the printer is ready to roll up the transfer, reduce the above with turpentine to about the thickness of cream; you will now find your ink is ready for the roller. Charge the roller liberally, and roll the roller well up on the slab. In so doing, you will find the turpentine evaporate, leaving the ink in beautiful condition for a first class transfer.

Should you find your ink get too stiff, reduce it with turpentine; be sure you roll your transfer one way only, namely, from you.—*Photographic News*.

MR. MUYBRIDGE'S PHOTOGRAPHS OF ANIMALS IN MOTION.

ONE of the latest topics of Parisian conversation has been the magnificent entertainment at the residence of M. Meissonier, where we had the pleasure of meeting a large number of the most eminent artists, scientists, and literati of Paris. The object of the renowned artist was to introduce to his friends Mr. Muybridge, of California, and afford them an opportunity of witnessing a very remarkable exhibition.

From time to time rumors have reached Europe of certain original and remarkable experiments in animal photography carried on by Mr. Muybridge at Palo Alto, in California, the residence of Governor Stanford, who had placed at Mr. Muybridge's disposition an exercising track and the use of his magnificent stud of horses, and was encouraging the investigations in a variety of other ways. During a visit to Paris last year, Mr. Stanford called upon Meissonier and exhibited to him a few specimens of the photographs. The great artist was immediately impressed with their value as an assistance to art, and they were a ready passport to his favor.

In reviewing the history of the attempts of artists to delineate the attitudes of animals in motion, one is struck with the comparatively little progress that has been made toward what we might call *absolute accuracy*. In the galleries of the Louvre we see examples of the horse in motion in the *bass-reliefs* of the Assyrian and Egyptian monuments, on the vases of Etruria, in the sculptures which adorned the temples of Greece and Rome, and in the paintings of the mediæval and modern artists, and in all, or nearly all, the original conventional attitudes are rigidly adhered to. Of all modern artists, and perhaps of all artists who ever lived, Meissonier has devoted the most attention to the subject, and has expended a fortune and years of his life in his attempts to solve the intricate and hitherto impossible problem of fixing the attitude of an animal in motion at a given moment. The patient investigations of Meissonier are proved in his unparalleled achievements, but even his quick perception and masterly rendition fail in *absolute accuracy*.

At last the Gordian knot is solved, and from the far-off land of California comes a man who is welcomed by the most eminent of living painters, accorded his friendship, and introduced by him, with a generosity equalled only by the greatness of his renown, to an assemblage of eminent men, such as is seldom found within the walls of one room.

Of the exhibition itself we need say but little; the applause which greeted the pictures renders it almost unnecessary for us to add our tribute to their praise. The pictures consisted of a large number of photographs projected with the aid of the oxyhydrogen light, the size of life, upon a screen, illustrating the attitudes assumed by a horse during each twelve inches of progress, while performing the various movements of hauling, walking, ambling, cantering, galloping, trotting, leaping, etc., many of these positions being foreshortened, and exhibited as seen from various points of view. In many of these pictures the successive actions of the muscular system were plainly distinguishable.

Other pictures illustrated the actions of the dog, the ox, the deer, etc., and the attitudes of men in the act of wrestling, running, jumping, and other athletic exercises. These, though few in number, were most admirably represented, and the warmest applause came from those whose greatest works on the canvas or in marble are those of the human figure.

With the aid of an instrument called the zoopraxiscope many of the subjects were exhibited in actual motion, and the shadows traversed the screen, apparently to the eye as if the living animal itself were moving, and the various positions of the horse and the dog, many of which, when viewed singly, are singular in the extreme, were at once resolved into the graceful, undulating movements we are accustomed to associate with the action of those animals.

The most remarkable and beautiful pictures were probably those of birds on the wing, so rapid is the action of the wing of a bird, and yet its movement was plainly visible in many of these, although the duration of the exposure of the negative was only the one-fifth thousandth part of a second. The exhibition of these pictures completed an entertainment at which the only dissatisfied man present was Mr. Muybridge himself, dissatisfied, however, only because he considers his results at present as simply suggestive; for he expresses his ability by availing himself of the wonderful progress which has been made in photographic manipulations since the execution of the pictures exhibited, to produce results which will as far eclipse his present works, as these do any photographs which preceded them. Indeed it is with this object that Mr. Muybridge has visited Europe, which presents the best field for the pursuance of the studies he may be said really to have initiated, and which in the opinion of the eminent host himself and of all those present will exercise a most powerful influence on future delineations of the attitude of animals in motion.

This subject is worthy of the earnest consideration of those gentlemen whose inclination and taste may induce

them to devote some portion of their attention to art, and who appreciate its progress.

A magnificent supper was provided for the guests, who, after the intellectual feast, were prepared to do ample justice to the more substantial matters of taste which were placed before them.

Among those present we noticed Gerome, Cabanel, Alexander Dumas, Ch. Garnier, Aimé Millet, Falqueire, De Neville, Léon Bonnat, Détaillé, Frenet, Jalabert, Emile Augier, Ridgeway Knight, Goupil, Steinheil, Worma, De Blowitz, Berne-Bellecour, Lefebvre, Lambert, Déroutede, Claretie, Albert Wolff, Guillaume, Victor Lefranc, Franceschi, De Saint Marceaux, Hetzel, Dr. Mallex, etc.—X, in *Amer. Register*.

A NEW METHOD FOR THE DETERMINATION OF THE MOLECULAR WEIGHTS, AND THE RESULTS OBTAINED BY IT.

The reinvestigation of the atomic weights is a subject which has not ceased to occupy experimenters; the investigation of the atomic weight of platinum by K. Seubert, of aluminum by J. W. Mallet, of glucinum by L. F. Nilson and O. Pettersson, of antimony by J. P. Cooke, are all of recent or not very distant date; and not only are the exact atomic weights far from being settled, but only the weights of a limited number of elements are considered as well established, and, what is more noteworthy, numerous discrepancies in the results obtained by different investigators exist and continue inexplicable in spite of the greatest efforts of the most skillful and scrupulous workers. The presentation of a new method for the determination of the exact values is, under these circumstances, more than a merely interesting matter; it is of practical importance, and the more so as by the new method the weights are derived directly from solids without any reference to gases, so that a means is afforded for testing the correctness of the theories and conclusions which are built on the behavior of gases and play so prominent a part in the determination of the atomic weights. If the results obtained prove correct, the whole question seems in a fair way of being finally settled, and with it more than one point of unusual interest and importance. The method is itself very simple; not so, however, the interpretation of some of the facts disclosed.

The amount of oxygen contained in potassium chlorate has been determined by a number of investigators, among whom are Maumené, Penny, Pelouze, De Marignac, Berzelius, Stas; and the results of their analyses vary only between a percentage of 39.143 and 39.200. From reasons which will become apparent subsequently, I shall use the term molecular weight instead of atomic weight, and the molecule of the compound consists then of one potassium, one chlorine, and a certain number of oxygen molecules.

According to Berzelius' result, which agrees closely with Stas', 10 parts contain 39.15 of oxygen, and this relation of weight between the oxygen and the remaining potassium

chloride allows of the conclusion that $\frac{100}{39.15} = 2.554$ is the

number of potassium chlorate molecules represented by 100; each single molecule having its share of oxygen, the number of times that the whole amount of this is contained in 100 must necessarily be the exact number of the molecules which are present, and 39.15, this amount, will also be the weight of one potassium chlorate molecule. In like manner, $100 - 39.15 = 60.85$, representing the same number of chloride

molecules, $\text{KCl} = \frac{60.85}{2.554} = 23.823$.

The number of molecules can only be an aliquot part of an integer, $9 \times 2.554 = 23.986$; neglecting the very small difference which can, without strain, be attributed to unavoidable inaccuracy of the analysis, 900 parts of potassium chlorate will represent 23 molecules; consequently,

$$\begin{aligned} \frac{900}{23} &= 39.1304 = \text{KClO}_3, \\ 100 - 39.1304 &= 60.8696 \times 9 \\ &= 547.8264 = 23 \text{ KCl}; \\ \frac{39.1304 \times 9}{23} &= 15.3118 = \text{O}_2. \end{aligned}$$

The relative weights of potassium and chlorine can from the given data be calculated. 60.8696 represent 2.555 KCl molecules; on the supposition that both constituents had the same weight, and that $30.4348 \text{ K} + 30.4348 \text{ Cl}$ represented exactly 2 instead of 2.555 KCl molecules, it follows that, when 60.8696 represent 2.555 molecules, the weight of one constituent must exceed that of the other by half the difference between 2 and 2.555, or 18 and 23, giving the proportion 18 to 30.5 and a percentage = $46.7533 + 53.2467$ as the relative weights of chlorine and potassium. This percentage, obtained without resort to any theory or assumption whatever, is minutely correct. $9 \times 60.8696 = 547.8264$ represent 23 KCl molecules, and consist, according to the percentage, of 256.1266 Cl + 291.7 K, which numbers, divided each by 23, give the molecular weights: $\text{Cl} = 11.136$; $\text{K} = 12.6825$; $\text{KCl} = 23.8186 + 15.3118 = 39.1304 = \text{KClO}_3$.

These constituent weights of K, Cl, and O are slightly smaller than one-third of the corresponding atomic weights: K, 39; Cl, 35.5; O, 48; from which it appears that H = 1 is not the smallest combining quantity; that one volume of H or Cl, etc., does not contain one but three molecular units. For, as the values found are in no manner speculative or hypothetical, but the real, actual weights of the molecules present, the weights of all gaseous, liquid, and solid compounds cannot be different; they must have the same one-third value. This conclusion is independent of the explanation of the small discrepancies in the exact values. As to the cause of these discrepancies and the answer to the question, Why are the weights in the solid compound slightly smaller than the corresponding weights of the gases? the following facts of a different nature have to be considered in connection with it.

The specific gravity of steam is generally stated to be 0.623, all modern chemical text books teaching 1 vol. of O + 2 vols. of H = 18 to form 3 vols. of steam, 1 vol. or liter of which is consequently = 9 or 0.8064 gram. The weight 18 is the sum of the weights of the constituent gases at 0° C. and 760 mm. pressure, and the specific gravity of steam = 9 is accepted to correspond likewise to that temperature and pressure; for the best authorities have established the weight of 1 cubic foot of steam at 100° C. and atmospheric pressure to be 0.0878 pound, which gives the specific gr. = 0.47, or 1 liter = 0.0078 gram. But the vapor of water which exists at

0° has not the assumed sp. gr. 0.623, which, therefore, is not real, but calculated from the coefficient of expansion of gases. 1 vol. of air, heated from 0° to 100°, expands to 1.3665 vols., and the temperature of 1 vol. of steam reduced from 100° to 0° would, at the same rate, produce a condensation of volume from 1 to 0.6335; these 0.6335 vol. weighing 0.47 gram, or more accurately 0.4552, 1 vol. will have the sp. gr. 0.623; and it is this calculated weight of imaginary steam which is assumed in chemistry.

It would seem that on such ground the chemical reasoning is untenable. The argument on which the theory of volumes chiefly rests is that, because equal volumes of different gases expand equally at equal increments of temperature, the number of molecules is the same in a volume of each. The condition of this relation is, therefore, the presence of a perfect gas, expanding at equal rate and conforming to Boyle's law. Steam is in that condition when its temperature is a little above the boiling point; it has at about 100° the same degree of tension which air has at 0°, and only when heated above that temperature does it behave exactly in the same manner as air heated above 0°. The difference of the boiling points has nothing to do with this relation; for the reason of the higher boiling point of steam is apparent; its specific gravity being smaller than that of air, a certain amount of heat is required to make up for the deficiency of weight in order to produce with the smaller weight an equal effect of tension. This same amount of heat, i. e. 100°, applied to air has quite another effect; it increases the volume from 1 to 1.3665, and it is therefore inadmissible to make the same temperature the standard of comparison. If the theory of volumes is to hold good, 1 vol. of steam at 100° must contain the same number of molecules as 1 of air at 0°. The condensation of 3 vols. of the constituent gases to 2 vols. of steam is certainly an observed and undoubted fact; these 2 volumes must, therefore, have the spec. gr. = 18, and contain the number of molecules which constitute the molecular weight, notwithstanding the temperature of the boiling point. When by cooling from 100° to 0° the volume is reduced to $\frac{1}{2}$, the number of molecules will still be the same, and the making up of one volume so condensed will be equivalent to an increase of molecules from 1 to 1.3665. It follows that the specific gravity of steam at 100° must be 0.623 and not 0.4552 as observed, and this is plainly to be inferred from the following facts.

Specific heat is, *ceteris paribus*, inversely as weight, and weight would follow directly from specific heat, if this depended in every instance on weight alone.

The specific heat of equal volumes of gases shows that this is not the case, there being differences for some different substances. But the differences can be taken into account by referring the specific heats of volume to that of hydrogen. Let s be the specific heat of equal weights, A that of equal volumes, then will the weights, calculated from the specific

weights of the principal gases thus derived are as follows:

Observ. sp. gr.	H.	s	A	calc. w.
0.0692	3.4046	0.2356	1
0.9713	0.244	0.2370	14.036
1.1056	0.2183	0.2412	15.974
2.44	0.1214	0.2682	35.26
0.9674	0.2479	0.2399	13.984
1.089	0.2315	0.2406	15.018
1.525	0.2288	0.3413	22.038
1.529	0.2164	0.3308	22.09
0.621	0.475	0.2950	8.975

All the numbers except the calculated weights are Regnault's. The very remarkable fact will be noticed that he quotes the specific gravity of steam = 0.621, though the specific heat is certainly that of real steam observed at a temperature above 100°, at which, according to his own determinations, the specific gravity of steam is only 0.4552. The reason for assuming the higher number is obvious. The specific heat of volume of steam calculated from 0.4552 is 0.2163, which would be entirely anomalous, being lower than the specific heat of volume of any other gas. One liter of steam would, in H units, be 6.57, a number irreconcilable with all chemical facts. Taking, however, the specific gravity at 100° = 0.623, steam behaves in every respect like the other gaseous compounds.

Again, steam having at 100° a power of tension equal to that of one atmosphere, this amount of heat is required to make up for the deficiency of weight as compared with the weight of an equal volume of air. The equivalent of this heat in weight is easily found.

The volume of air being doubled by heating it from 0° to 273°, and the rate of expansion being uniform at all temperatures, this amount of heat will be equal to the weight of 1 volume of air = 14.43, and 100° will represent a weight = 5.2857; this gives for the specific gravity of steam at 100°, $14.43 - 5.2857 = 9.1443$. The theoretical specific gr. = 9 is that of the perfect gas which steam becomes at a little above 100°; taking into account that the specific heat of volume of steam is greater than that of air, the temperature at which the sp. gr. is 9 would be 103.38°.

The evidence of the chemical as well as the physical facts is, therefore, to the effect that steam at a little above 100° has the spec. gr. 0.623, and if this is so, a startling fact of the greatest theoretical and practical importance follows. According to Regnault, 1 gm. of water = 1 cubic centimeter at 4°, fills when converted to steam of atmospheric tension a space of 1,669 cubic centimeters = 1.669 liters, which at 0.8064 gram a liter, represent a weight of 1.3459 gram. These having been yielded by 1 gm. of water, an increment of weight = 0.3459 gram., or over one-third, is found which would have been produced in some way. A variation of weight would at once explain the discrepancy between the observed specific gravity of steam and that inferred from chemical and physical facts. In every instance, as far as I have been able to discover, not the weight of the steam has been determined, but that of the water used for its production, the weighing of the gas being considered to yield too uncertain results. Whether the conclusion of the variability of weight is well founded can only be settled by new experiments; but the evidence of its correctness, derived from a multitude of connected facts which are met with in the further inquiry concerning the molecular weights, seems to amount to certainty.

The difference between water and steam, to which alone the cause of the variation of weight could be ascribed, is the difference of state, and if this is so, the explanation of the deviation of the weights found in potassium chlorate from the atomic weights is, that the former represent weights of the solid, the latter weights of the gaseous state, and as the gain of weight in steam involves merely a change from the

liquid to the gaseous state, it is to be expected that, when the difference is between the solid and the gaseous state, the gain of weight will be greater than that found in steam.

Physical science does not teach the nature of the processes which produce a change of state; but there can be little doubt that chemical action is the producing agent; two or more identical molecules of one and the same substance combining in like manner as do molecules of different substances, liquid molecules will result from gaseous and solid from liquid. It is at least certain that an expenditure of force is required for each change, as is indicated not only by the latent heats of the gaseous and the liquid state, but also by the general fact that changes of state are brought about by means of pressure and temperature. From these considerations a greater loss of weight must be expected in the potassium chlorate molecules than in those of water, and not only is this found to be the case, but the respective values bear a simple relation to each other.

The gain of weight in steam being 0.3459 for 1 gm. of water, will be $0.0896 \times 0.3459 = 0.030985$ if the unit is H = 1, that to which all atomic weights are referred. 2,000 c.c. of steam or 2 vols. represent 3 molecules in units of the one-third value; 1,669 c.c. the relative volume of steam, therefore 2.5035 molecules giving for the molecular weight in the

liquid state $\frac{14.43}{2.5035} = 5.764$. The gain of weight being 0.030985 for H = 1, the molecular weight ought to be

$5.764 \times 1.030985 = 5.94197$. If, as seems likely, the volume is a multiple without fraction of 18, and = 2,016 c.c., 1,669 c.c. represent 2.4836 vols., the mol. w. is = 5.81, and the agreement complete, showing the correctness of Regnault's relative volume.

15.3118, the amount of oxygen found in one potassium chlorate molecule, has to be multiplied by 1.04495 to be increased to 16, the weight of the gaseous state. Two-thirds of 0.04495 = 0.02996 is almost identical with 0.030985, the gain of weight in steam. It is thus verified that there is a definite relation between the latter and the difference of weight in the one-third values, and that the difference is greater for the solid than the liquid in the proportion of 3 to 2.

The comparison has, so far, been between the oxygen contained in a solid and that contained in a liquid, the only difference being that of state.

But the state depending on an expenditure of force, probably on chemical action, the variation of weight for different elements which are in the same state, will also be different, if the state in which elements naturally exist is not the same for all, if the distance between the natural and the state under observation is unequal for different classes of elements, more chemical action being required in one case than in another to bring about the same state. That elements exist naturally in different states needs no proof, for they vary in this respect within the wide limits of the almost incondensable gases and the equally irreducible solids, boron, carbon, silicon, etc. Of the three constituents of potassium chlorate, potassium exists, under ordinary conditions, as a solid only, chlorine and oxygen as gases, one of which is readily liquefied, the other only by extraordinary means. If, therefore, the weights, K, 13.6826; Cl, 11.136; O, 15.3118, are multiplied by one and the same number, 1.04495, the products are for 3 molecules; K, 39.7572; Cl, 34.9692; O, 16; only for oxygen is the exact weight obtained; the other two numbers are not only not the exact weights, but they deviate from them inversely, that for K being too great, for Cl too small. If, for the sake of brevity, the number by which a combining weight has to be multiplied in order to make up for the loss of weight consequent on a change of state, be designated as the coefficient c of the variation of weight, it follows that each of the constituents of potassium chlorate has its own coefficient, and that the coefficient of chlorine must be greater, of potassium smaller, than that of oxygen. In like manner must the coefficients of all different classes of elements be expected to vary.

If the conclusion of the variation of weight is well founded the dependency of the amount of variation on the inequality of the natural state involves, as a necessary consequence, discrepancies in the results of the determination of the atomic weights. Discrepancies are inevitable if the combining weights found on analysis are referred to the weight of one and the same gas, the variation of weight being different for different elements; and there will be additional discrepancies, if in some cases the weights are referred to one class of gases, for instance hydrogen or oxygen, in others to another class of different coefficient, as chlorine.

The existence of irreconcilable discrepancies in the results of equally skillful and trustworthy experimenters is now strong evidence of the variability of weight.

The difference of the coefficients for different elements involves the difficulty of their determination. Neither the atomic weight of potassium nor of chlorine is sufficiently well established to derive the exact coefficients in the same manner as for oxygen. It is, however, possible to determine the combining weight of some element, for instance, sulphur, whose atomic weight in the gaseous state, $8 = 32$, is as well established as O = 16, and it is further to be expected, as a definite relation between the deviations of weight consequent on the difference of state has been found in the oxygen of steam and that of potassium chlorate, that similar relations exist for different classes of elements which are in the same state.

For the purpose of obtaining for other elements the combining weights corresponding to those already found, only such of the experimental determinations of reliable experimenters are available which are the result of direct observation and do not depend on a reference to any atomic weight. For instance, Berzelius found that 100 KCl yield 192.4 AgCl; this number agrees closely with Marignac's, who found 192.35, and is, as further investigation shows, minutely correct. KCl being = 23.8186, AgCl is = 45.827; and Cl, 11.136, Ag is = 34.691. Stas, an equally good authority, found that 100 Ag, dissolved in nitric acid, required for precipitation 69.103 KCl, which gives, if Ag = 34.691, KCl = 23.9235. This wide discrepancy is due to the fact that Stas' determination of silver is based on the atomic weight Ag = 108. If O = 15.3118, then is H 1 = 0.957, and Ag 108 = 108.356, 1 mol. = 34.432; with this value Stas' number gives for KCl, 23.8074, which agrees closely with Berzelius' result. The atomic weight of silver is thus shown to be widely at fault, and as this element is the one chiefly resorted to for the determination of the atomic weights, the cause of many existing discrepancies is obvious.

Berzelius determined further with complete correctness that 100 BaCl₂ yield 138.0608 AgCl; AgCl, 45.827; BaCl₂ = 33.1933; Ba = 23.0573.

100 BaCl₂, according to the same authority, yield 112.18

BaSO₄, BaCl₂ 33.1938; BaSO₄ = 37.2363; SO₄ = 15.1789; S = 4.971.

If the atomic weights are referred to Cl 35.5 as unity, instead of H = 1, the atomic weight of sulphur corresponding to Cl 11.136 is $\frac{16}{35.5} \times 11.136 = 5.019$, which number

differs but little from 4.971. The mean of the two values is 4.995, which proves, on further research, to be the nearly exact combining weight. The coefficient required to make with this weight 38 = 16 is 1.0676, which is equal to the coefficient of oxygen increased by one-half; for $1 + 0.04494 \times 1.5 = 1.067425$. The weight Cl 11.136 multiplied by 1.0676 gives exactly 38.1 = 35.66, or 9 molecules = 107. One-half of 0.0676 is 0.0338; $12.6826 \times 1.0338 \times 3$ gives 3K = 39.33, or 9 molecules = 118.

By means of Prof. J. W. Mallet's excellent determinations* the combining weights of Li, Na, and Mg are found as follows:

46.44 Li₂SO₄ required for precipitation 102.94 BaCl₂·2H₂O
50.675 Na₂SO₄ " " 86.92 " "
46.625 MgSO₄ " " 84.873 " "

BaCl₂, as already found, is = 33.1938; H₂O₂ = 5.742; BaClH₂O₂ = 38.9353; LiSO₄ consequently = 17.565; NaSO₄ = 22.69953; MgSO₄ = 19.13476; SO₄ with the weights found is = 15.2035; Li therefore = 2.3615; Na = 7.496; Mg = 3.9313.

Pelouze found that 100 Ag required for precipitation 54.144 NaCl; atom. w. of Ag = 34.452; NaCl = 18.6586 and Na = 7.3176. Using for Li and Na the coefficient of K = 1.0338, and for Mg that = 1.0676, the numbers Li 2.3615; Na 7.5176; Mg 3.9313, give for 3 molecules Li = 7.324; Na, 23.315; Mg, 12.5914. These values correspond very nearly to resp. 7.33; 23.33; 12.66. Assuming now that 9Na are =

70, the exact combining weight is $\frac{70}{1.0338 \times 9} = 7.5235$, the

minute correctness of which can be demonstrated.

Berzelius found the percentage of water in borax (Na₂O(B₂O₃)₁₀H₂O) = 47.1; the weight of the anhydride of sodium bi-borate is, therefore, 52.9. The formula corresponds to the molecular composition NaO.3B₂O₃.5H₂O, showing 10 molecules of oxygen in the water, 6 in the boric acid, and 1 in the oxide of sodium. The amount of O present in 47.1 H₂O is 41.866; there are consequently in the acid 25.12 O; in the oxide 4.1866 O, which represent 1.44055 mols., O being = 2.552; if Na = 7.5235, 1.44055 mols. are = 12.3426, and 16.5293 NaO deducted from 53.9 leave 36.3708 boric acid, which are 2 × 1.44055 = 3.2811 mols., B₂O₃ is consequently = 11.0849.

O₄ being = 7.6559, B₂ are = 3.439, and B = 1.713, which multiplied by the coefficient 1.0676 gives 9B = 10.983; if

the exact number is 11, the calculated weight is $\frac{1.0676 \times 9}{1.0338 \times 9} = 1.14483$.

The calculated weights give NaO = 10.07548; 2B₂O₃ = 22.18073; 5H₂O = 28.7098, and a percentage of water = 47.0914. This minute coincidence with the observed value 47.1 is strong evidence of the correctness of all the conclusions arrived at, and in particular of the absolute correctness of the calculated weights of Na and B.

The calculated weight of Li is $\frac{23}{1.0338 \times 9} = 2.3645$; of

Mg $\frac{38}{1.0676 \times 9} = 3.9549$; LiSO₄ = 17.568; NaSO₄ = 22.727; MgSO₄ = 19.1584. If n = number of molecules, then

46.44 Li₂SO₄ = 102.94 BaCl₂·2H₂O;
n = 2.64347; n = 2.64388;
50.675 Na₂SO₄ = 86.92 BaCl₂·2H₂O;
n = 2.23273; n = 2.23243;
46.625 MgSO₄ = 94.873 BaCl₂·2H₂O;
n = 2.4337; n = 2.437.

The agreement of the corresponding numbers, it will be seen, is as complete as in this kind of experiments seems obtainable.

Ca 40 is = 38.28, and 1 mol. = 6.38, if H = 0.957. This number, 6.38, is slightly too small. The results of the following analyses of CaOSO₄·2H₂O do not differ much from each other:

CaO, 33.0; SO₄, 46.0; H₂O, 21.0 { Buchholz.
" 33.0; " 45.5; " 21.5 { Klaproth.
" 32.8; " 45.3; " 22.0 { Berthier.
" 32.0; " 46.0; " 22.0 { Bergmann.

The percentage of CaO varies between 32 and 33; choosing Berthier's number 32.8, which is nearest the mean, the remaining sulphuric acid and water are = 67.3 and SO₄H₂O₂ = 18.3934, CaO is = 8.9773 and Ca = 6.4353. Sr 87.5 is, when H = 0.937, = 83.7373, and 1 mol. = 13.95625.

Strontianite contains

1. CO₂, 30.31; SrO, 65.6; CaO, 3.47 (Stromeyer).
2. " 30.8; " 65.3; " 3.82 (Redicker).

The mean of the two analyses is

CO₂, 30.555; SrO, 65.45; CaO, 3.645.

The combining weight of C corresponding to S 4.995 is $\frac{12}{4.995} \times 4.995 = 1.873$; CO₂ therefore = 6.9773. If Ca = 6.4258, 3.645 CaO will combine with 2.8333 CO₂, leaving 27.7218 CO₂ combined with 65.45 SrO, and SrO is = 16.4731; Sr = 13.9211. This value does not differ much from the atom. w., 13.9562.

Ag 34.601 has to be multiplied by 1.0377 to make 3 Ag = 108. Using this coefficient for Ca, Sr, and Ba, the product for 6 molecules is:

Ca, 6.4258; 6 Ca = 40.008;
Sr, 13.9211; 6 Sr = 86.668;
Ba, 22.0573; 6 Ba = 137.333.

These numbers closely agree with the atomic weights, and again indicate that in every case the sum of 9 molecules is an integer. The exact weights of Ca and Sr, calculated accordingly, are, Ca $\frac{60}{1.0377 \times 9} = 6.4244$; Sr, $\frac{130}{1.0377 \times 9} =$

13.9197. It has thus been verified that the coefficients for different

* See "Amer. Journal of Science and Arts," vol. xxviii. (1850), p. 353.

classes of elements bear a simple relation to each other; the coefficient is for

Li, Na, K = 1.0338
Ca, Sr, Ba, Ag = $1 + 0.0338 \times 1.17$ = 1.0377
H, O, N = $1 + 0.0338 \times 1.39$ = 1.04494
B, C, Mg, S, Cl = $1 + 0.0338 \times 2$ = 1.0676

The first three coefficients mark distinctly chemically different classes, the alkalis, the alkaline earths, and the so called permanent gases. The chemical properties of the first and second differ but little, and so do the coefficients. That chlorine is not found in the same class with oxygen is in harmony with other physical facts. For the determination of the coefficients of the remaining elements it is important to notice that the coefficient in general increases with the number of molecules contained in unit of volume, to wit:

K, 1 vol. 0.866 = 12.496 = 0.985 mol.
Na, " 0.97 = 14 = 1.86 mols.
Li, " 0.589 = 8.499 = 3.595 "

That for Na and Li the number of molecules is greater than for K is due to the disparity of the mol. weights.

Ca, 1.58 = 22.8 = 3.549 mols.
Sr, 2.5 = 36.075 = 2.59 "
Ba, 3.75 = 54.113 = 2.453 "
Ag, 10.47 = 151.1 = 4.355 "
B, 2.08 = 38.673 = 3.78 "
C, 1.865 = 27.3 = 14.53 "
Mg, 1.74 = 25.11 = 6.349 "
S, 1.93 = 27.85 = 5.575 "

It will be seen that, in general, the number of molecules in unit of volume increases the greater the coefficient, and as for all the remaining elements examined this number is large, it may be expected that they have all the largest coefficient, and this is found to be the case.

The atomic weights agree in some cases entirely with the calculated, and in many the difference is very slight; it will therefore facilitate the inquiry to present the calculated weights side by side with the atomic, because it will be unnecessary to prove the correctness of the former when they agree with the latter. For this purpose the following table has been drawn up: Column I. shows the calculated combining weights; II. the corresponding atomic weights when H = 0.957; III. the same referred to Cl 35.5 when Cl 11.136 is

unit, for instance H = $\frac{1}{35.5} \times 11.136 = 0.31369$; IV. the coefficients of the variation of weight; V. the calculated weight corresponding to the gaseous state, for 9 molecules; VI. the same for the number of molecules corresponding to the adopted atomic weights; VII. these atomic weights.

	I.	II.	III.	IV.	V.	VI.	VII.
H	0.319	0.319	0.31369	1.04494	3	1	1
B	1.1448	1.1696	1.1502	1.0676	11	11	11
G	1.457	1.488	1.4743	1.0676	14	9.33	9.4
N	1.489	1.488	1.4639	1.04494	14	14	14
C	1.8733	1.914	1.882	1.0676	18	13	12
Si	2.2806	2.233	2.1958	1.0676	22	29.33	28
Li	2.3644	2.233	2.1958	1.0338	22	7.33	7
O	2.55198	2.55198	2.5095	1.04494	24	16	16
Al	2.914	2.9135	2.865	1.0676	28	28	27.4
P	3.3311	3.2968	3.2415	1.0676	32	32	31
Mg	3.9548	3.828	3.7642	1.0676	38	25.33	24
S	4.9655	5.104	5.019	1.0676	48	32	33
F	5.62	6.031	5.96	1.0676	54	18	19
Ca	6.4244	6.38	6.2738	1.0377	60	40	40
Na	7.5235	7.337	7.2149	1.0338	70	23.33	23
As	7.91	7.975	7.8422	1.0676	76	76	75
Cr	8.3259	8.3578	8.2187	1.0676	80	53.33	52.4
Mn	8.743	8.7725	8.6265	1.0676	84	56	55
Fe	8.95	8.993	8.7833	1.0676	86	57.33	56
Sr	9.158	9.4105	9.254	1.0676	88	117.33	118
Ni	9.36	9.4105	9.254	1.0676	90	60	59
Co	9.5748	9.4105	9.254	1.0676	92	61.33	59
Cu	9.9903	10.1123	9.944	1.0676	96	64	63.4
Zn	10.407	10.3675	10.1940	1.0676	100	66.66	65
Cl	11.136	11.3245	11.136	1.0676	107	35.66	35.5
K	12.6826	12.441	12.234	1.0338	118	39.33	39
Se	12.488	12.6648	12.4535	1.0676	120	80	79.4
Sb	12.9032	12.9726	12.7507	1.0676	124	124	122
Sr	13.9197	13.9562	13.724	1.0377	130	86.66	87.5
Cd	17.69	17.864	17.566	1.0676	170	113.33	112
Te	20.399	20.416	20.076	1.0676	196	130.66	128
Au	20.8148	20.948	20.599	1.0676	200	200	197
Ba	22.0573	21.8515	21.488	1.0377	206	137.33	137
Bi	22.0637	22.33	21.96	1.0676	212	212	210
Br	25.3941	25.52	25.095	1.0676	244	81.33	80
Pt	30.5978	31.4853	30.961	1.0676	294	196	197.4
Hg	31.8467	31.9	31.37	1.0676	306	204	200
Pb	32.4712	33.0165	32.467	1.0676	312	208	207
Ag	34.601	34.452	33.88	1.0377	324	108	108
I	40.381	40.513	39.84	1.0676	388	139.33	127

The mode of calculation will, with the statements already made, need no special explanation; it was necessary to find the combining weight, which, if correct, would give, when multiplied by 9 × 1.0676, a whole number; or if approximately correct, would indicate that number, which divided by 9 × 1.0676, gives the exact combining weight.

A glance at columns II. and III. shows the discrepancies which are inevitable because the combining weights of chlorine and oxygen found in potassium chlorate have to be multiplied by different numbers in order to be increased to the weight of the gaseous state. It appears further that of the atomic weights referred to H, about 17 agree with the calculated weights, more or less nearly; of those referred to Cl, only 9. Among those that disagree widely is fluorine, the calculated weight of which has been derived from the following data: 1. H. Davy's percentage of CaF₂ (= Ca F), viz.:

53.313 Ca + 46.687 F;
Ca, 6.4244; F = 5.626.

2. Berzelius' percentage of fluoride of silicon:

29.32 Si + 71.68 F
Si, 2.2896; F = 5.5975

3. The following percentages of toparaz, which show the exact composition of the different varieties of the compound,

and prove the correctness of the calculated weights of Si, Al and F.

2 SiO₂.4Al₂O₃.F₂:
34.24 SiO₂; 57.45 Al₂O₃; 14.99 F₂; } Berzelius
34.01 " 58.99 " 15.06 "
34.36 " 57.74 " 15.02 "
mean 34.2 " 57.86 " 15.02
n = 0.893; n = 0.8821; n = 0.8909

2 SiO₂.4Al₂O₃.F₂:
33.53 SiO₂; 56.54 Al₂O₃; 18.02 F₂; } Ramelsberg
33.37 " 56.76 " 18.54 "
33.56 " 56.28 " 18.30 "
mean 33.486 " 56.526 " 18.486 "
n = 0.8046; n = 0.862; n = 0.8224 "

35.66 " 55.16 " 17.79 " } Forchhammer
35.39 " 55.96 " 17.35 "
mean 35.525 " 55.56 " 17.57 "
n = 0.9272; n = 0.847; n = 0.7816;

The percentage of the silicic acid is in these two analyses too large at the expense of the fluorine; the mean between 0.9272 and 0.7816 is 0.8544, and the number of molecules then
n = 0.8544; n = 0.847; n = 0.8544.

2 SiO₂.3Al₂O₃.F₂:
38.43 SiO₂; 51.00 Al₂O₃; 17.09 F₂; (Berzelius)
n = 0.9922; n = 1.0367; n = 1.014;

39.04 " 51.25 " 18.48 " } Forchhammer
n = 1.0301; n = 1.0418; n = 1.006.

3 SiO₂.6Al₂O₃.F₂:
33.73 SiO₂; 57.39 " 16.12 " } Ramelsberg
32.38 " 55.32 " 16.12 "
33.28 " 55.33 " 16.12 "
mean 33.13 " 56.01 " 16.12 "
n = 0.57; n = 0.569; n = 0.5737.

De Marignac found that 100 Ag required for precipitation 110.36 KBr;
atom. w. of Ag, 34.452; KBr = 38.002; Br = 25.3194.

In 100 parts of embolite were found

1. 69.14 Ag; 14.63 Br; 16.23 Cl; } Domcy
Ag, 242.837; Br, 51.39; Br = 25.695;
Cl, 55.68; Br = 50.191; Br = 25.955;
mean Br = 25.3952.

2. 66.95 Ag 19.9 Br; 13.15 Cl; (Yorke.)
66.94 " 19.82 " 13.18 " (Field.)

Ag, 173.455, Br, 51.3575; Br = 25.6787;
Cl, 33.408, Br, 50.2377; Br = 25.1189;

mean Br = 25.3989
c. w. Br = 25.3941.

Dumas burned silver iodide in a stream of chlorine, and weighed the silver chloride produced.

35.30 AgI gave 21.49 AgCl;
AgCl, 45.827; AgI = 75.0629; I = 40.371;
70.11 AgI gave 42.81 AgCl;
AgI = 75.0492; I = 40.357
calc. w. I = 40.381.

The exact weights of bromine and iodine having been found, that of antimony is obtained by the careful and ac-

* All the numbers used here and elsewhere if the source is not specially indicated, will be found in one or the other of the following works: Berzelius' "Lehrbuch der Chemie;" Gmelin's "Handbuch;" Dana's "System of Mineralogy;" Watts' "Chem. Dictionary."

curate determinations of Prof. J. P. Cooke. He found in some of his experiments* that

330.58 SbBr₃ yielded 517.82 AgBr;
AgBr, 00.0851; SbBr = 38.353; Sb = 12.9589;
274.95 SbBr₃ yielded 430.76 AgBr;
SbBr = 38.35186; Sb = 12.9578.

The same amounts of antimonious bromide required for precipitation:

330.50 SbBr₃ 297.49 Ag;
atom. w. Ag, 34.452; SbBr = 38.2834; Sb = 12.8898;
274.95 SbBr₃ 247.45 Ag;
SbBr = 38.287; Sb = 12.8929.

These two determinations having been made by the volumetric method, the amounts of silver are based on the atomic weight. In previous experiments the same experimenter had found:†

186.21 SbBr₃ to yield 292.16 AgBr;
AgBr, 00.0851; SbBr = 38.2956; Sb = 12.9015;
186.5 SbBr₃ to yield 292.08 AgBr;
SbBr = 38.2976; Sb = 12.9035;
calc. w. Sb = 12.9052.

118.77 SbI₃ yielded 167.27 AgI;
AgI, 75.073; SbI = 53.3055; Sb = 12.9245;
461 SbI₃ yielded 640.7 AgI;
SbI = 53.2684; Sb = 12.8874.‡

The mean of the latter two numbers gives Sb = 12.90595, which is the calculated weight.

Domeykite consists of

1. 28.26 As + 71.48 Cu (Field);
2. 28.36 " + 71.64 " (Domeyko);
As, 7.91; 2Cu = 19.9814; Cu = 9.9907;
2Cu, 19.9806; As = 7.9097.

Berzelius found in Cu₂Se,

64Cu + 40Se
2Cu, 19.9806; Se = 12.4875;
calc. w. Se = 12.488

H. Rose found in PbSe,

27.59 Se + 71.81 Pb
Se, 12.488; Pb = 32.506
atom. w. (Cl, 35.5) Pb = 32.467
calc. w. Pb = 32.4712

100 CdI₂ (= CdI) contain

69.46 I + 30.54 Cd (Stromeyer);
I, 40.381; Cd = 17.7546.

100 CdCl₂ (= CdCl) contain

38.61 Cl + 61.39 Cd (Stromeyer);
Cl, 11.136; Cd = 17.7062;
calc. w. Cd = 17.69.

81.7 BaCl₂ correspond to 100 BaCrO₄ (Widenstein);

BaCl, 33.1933; BaCrO₄ = 40.6283;
CrO₄ = 18.571; Cr = 8.363
calc. w. Cr = 8.3259

97.575 PbCrO₄ correspond to 100 PbNO₃ (Berlin);

PbCrO₄, 51.005; PbNO₃ = 52.2725;
PbNO₃, 52.247; PbCrO₄ = 50.98.

100 prts. of 2MnOCO₃.H₂O (= 4MnOCO₃.H₂O) contain

35.4 CO₂; 57.3 MnO, 7.3 H₂O (Ure);
CO₂, 6.9773; MnO = 11.2983; Mn = 8.7418
calc. w. Mn = 8.7415.

100 FeI₂.5H₂O contain

63.64 I; 14.14 Fe; 22.22 H₂O (J. D. Smith);
I, 40.381; Fe = 9.9722;
calc. w. Fe = 9.9496.

Fulda found in NiOSO₄.7H₂O,

28.54 SO₃; 26.76 NiO; 44.43 H₂O,
SO₃, 12.5514; NiO = 11.8623; Ni = 9.31.

Arfvedson found in NiS,

34.26 S + 64.35 Ni
S, 4.9955; Ni = 9.332

100 NiO.P₂O₅ (= NiOP₂O₅) contain

65.6 P₂O₅ + 34.4 NiO (Maddrell);
P₂O₅, 22.7533; NiO = 11.9316; Ni = 9.3796.

109 NiO, with the calc. weights, contain. 78.587 Ni;

W. J. Russell obtained§ in one of his experi-

ments 78.584 "

In another 78.588 "

Marignac found 3Ni = 29.35, corresponding to 78.581 "

Erdman & Marchand, 3Ni = 29.3 " 78.553 "

100 CoBr₂ contain

72.57 Br + 27.43 Co (Berthelot);
Br, 35.3941; Co = 9.5984.

100 CoOP₂O₅ (= CoOP₂O₅) contain

65.21 P₂O₅ + 34.79 CoO (Maddrell);
P₂O₅, 22.7533; CoO = 12.139; Co = 9.587.

Winkelblech found CoOH₂ to consist of

19.13 H₂O + 80.89 CoO;
H₂O, 5.742; 2CoO = 24.2318; Co = 9.5586.

He found in Co₃O₃.3H₂O,

24.26 H₂O; 21.62 O; 53.88 Co;
3H₂O, 17.236; 4Co = 38.232; Co = 9.555

3O, 7.6559; 2Co = 19.082; Co = 9.531.

Schneider and Sommaruga found 3Co = 30, which gives,

3H = 0.937,
Co = 9.57
calc. w. Co = 9.5748.

Dumas obtained a smaller number, but the probable cause of the discrepancy can be pointed out. Pure CoCl₂ was precipitated with AgNO₃, and the resulting AgCl reduced by hydrogen. In one of the experiments were obtained

249.2 Ag from 414.05 CoCl₂,
atom. w. Ag, 34.452; CoCl = 20.738; Co = 9.602.

This is nearly the calculated value, and it seems therefore that the silver has been determined by means of the argentic

nitrate solution required for precipitation, and on the base of the atomic weight of silver.

100 SnS contain, according to Berzelius and J. Davy,

21.4 S + 78.6 Sn;
S, 4.9955; 2Sn = 18.346; Sn = 9.173.

100 SnCl₂ contain

37.78 Cl + 62.22 Sn (J. Davy);
Cl, 11.136; 2Sn = 18.34; Sn = 9.17

Mallet found in stannite

29.46 S; 26.85 Sn; 29.18 Cu;

28, 9.991; Sn = 9.105

Cu, 9.9903; Sn = 9.1923

mean Sn = 9.1487

calc. w. Sn = 9.158

100 ZnBr₂ contain

70.75 Br + 29.25 Zn (Berthelot);

Br, 25.3941; Zn = 10.4986;

Monheim found in calamine (Si₄O₃.Zn₃O₄.H₂O₂),

24.85 SiO₂; 66.4 ZnO; 7.49 H₂O;

SiO₂, 4.84158; ZnO = 12.937; Zn = 10.385.

Vannuxem and Keating found in willemite (Si₂O₃.Zn₂O₄),

25.44 SiO₂ + 68.06 ZnO;

SiO₂, 4.84158; ZnO = 12.9327; Zn = 10.4007

calc. w. Zn = 10.407.

Wehrle found in bismuthinite,

18.28 S + 80.96 Bi;

S, 4.9955; Bi = 22.1223.

Schneider found in 100 Bi₂O₃ from 10.318 to 10.306 O;

10.366 O + 89.634 Bi;

O, 2.552; Bi = 22.066

calc. w. Bi = 22.0637.

100 SnHg₂Cl₄ (= SnHgCl) contain

17.68 Sn; 61.31 Hg; 21.09 Cl (Capitaine);

Sn, 9.153; Hg = 31.758.

100 Hg₂Cd contain

21.74 Cd + 78.26 Hg (Stromeyer);

Cd, 17.69; 2 Hg = 63.63

Hg = 31.84

calc. w. Hg = 31.8467.

178.2 BaSO₄ correspond to 100 Au (Levol);

BaSO₄, 37.2607; Au = 20.9095.

74.5 KCl correspond to 106.32 Au (Berzelius);

KCl, 23.8186; 3Au = 62.766

Au = 20.922

142.9 Hg precipitate 93.55 Au (Berzelius);

Hg, 31.8467; Au = 20.8485

calc. w. Au = 20.8148.

Klaproth found in 100 parts of nagayagite,

Te, 32.20 = 1.5785 mols.

S, 3.00 = 0.6006 "

2.1701

Pb, 54.00 = 1.663 mols.

Au, 9.00 = 0.4324 "

Ag, 0.50 = 0.0144 "

Cu, 1.30 = 0.0650 "

2.1749

100.00

Berzelius found that 69.81 PtCl₂.2 KCl (= PtCl₂.KCl) lost by ignition 20.24 Cl, leaving 49.57 KClPt.

2Cl, 22.272; KCl Pt = 54.5465

KCl = 23.8186

Pt = 30.7379

He also found in 100 PtCl₂ (= PtCl),

26.7 Cl + 73.3 Pt;

Cl, 11.136; Pt = 30.572.

K. Seubert found* in 100 PtCl₂.2 KCl (= PtCl₂.KCl),

29.21 Cl; 40.11 Pt; 30.685 KCl;

2 Cl, 22.272; Pt = 30.582

calc. w. Pt = 30.5978

From the evidence produced, the general correctness of the calculated weights may be inferred; for their agreement with experimental results is minute and complete in all cases in which observations of the best authorities are at hand; and if further research should necessitate modifications, it is to be expected that they will be few in number and slight.

These weights are moreover independent of all theory, for they are the actual combining weights of the solid state.

But there is evidence also of the correctness of the calculated weights of the gaseous state. Of the 40 elements examined these weights coincide in 8 cases with the atomic, in 5 they are smaller, in 37 greater. In general, the observed vapor densities are greater than they should be according to the atomic weights.

In the following the vapor densities of some elements and compounds, observed by Deville and Troost,† are compared with the calculated and the atomic weights;

P, at 500° C, 4.35 = 62.86;

at 1040°, 4.5 = 65.03;

mean 63.95

calc. w. 18 P = 64.00

atom. w. 18 P = 63.00

As, at 564°, 10.6 = 153.18;

calc. w. 18 As = 152.00

atom. w. 18 As = 150.00

Se, at 1420°, 5.68 = 82.08

calc. w. 6 Se = 80.00

atom. w. 6 Se = 79.40

Te, at 1890°, 9.00 = 130.06

at 1430°, 9.08 = 131.025

mean 130.543

calc. w. 6 Te = 130.66

atom. w. 6 Te = 128.00

Cd, at 1040°, 3.94 = 58.85

calc. w. 3 Cd = 56.66

atom. w. 3 Cd = 56.00

Al₂Cl₆, at 350°, 9.32

9.38

at 440°, 9.33

9.34

9.37

mean 9.348 = 134.80

calc. w. 3 Al₂Cl₆ = 135.00

atom. w. Al₂Cl₆ = 133.9

2

Al₂Br₆, 18.62 = 268.7

calc. w. 3 Al₂Br₆ = 272.0

atom. w. Al₂Br₆ = 267.4

2

Fe₂Cl₆, at 440°, 11.42 = 168.63

11.37 = 164.09

calc. w. 3 Fe₂Cl₆ = 164.33

atom. w. Fe₂Cl₆ = 162.50

2

Hg₂Cl₂, 8.21 = 118.47

8.35 = 120.05 (Mitscherlich)

calc. w. 3 Hg₂Cl₂ = 119.83

2

atom. w. Hg₂Cl₂ = 117.75.

4

It will be seen that the calculated values agree with the observed better than do the atomic in all cases except that of the bromide of aluminum.

So far the inquiry and its results. Of the latter not the least interesting is the confirmation of Prout's hypothesis in the modified form that the sum of 9 molecules is in every instance a whole number. The consideration of other obvious conclusions is deferred for another occasion.

San Francisco, Cal., Oct. 13, 1881. EDWARD VOGEL.

WATER GLASS.

In 1640 Von Helmont discovered that when in the preparation of glass from sand and alkali an excess of alkali was used the glass dissolved in boiling water, but it was not until 1828 that water glass as now known was prepared and practically utilized by Von Fuchs, in *stereochromy* or *solid color painting*, in mural and monumental decoration, and for the preparation of various cements and artificial stones. Water glass, soluble glass, or silicate of soda, as it is variously called, possesses, when properly prepared, many unique and valuable properties. In cold water it is nearly insoluble, or dissolves very slowly. In boiling water it dissolves with facility and remains in solution when the latter has cooled. Water containing 30 per cent. of the glass in solution is of a sirupy consistence, and may be used as a transparent varnish on many substances; on drying it forms a glassy coating that resists moisture and change of temperature very well. It has been used extensively as a vehicle for certain pigments to form paints known as silica paints. These have the advantage over all paints or varnishes of being incombustible, and when used on woodwork serve in a measure to prevent sudden ignition of the wood by contact with flame. They are also serviceable in painting theatrical scenery, cloth saturated with a dilute water glass varnish becoming unflammable. The pigments used in these paints are: zinc white, barytes, chrome green, chrome oxide, chrome red or orange, cobalt ultramarine, zinc yellow, ultramarine, cadmium sulphide, ochre, etc. Chalk mixed with water glass forms on drying a very compact stone as hard as marble; bone ash, zinc white, and magnesia with water glass form similar stones. Ransome's artificial stone is prepared by mixing sand with water glass solution to form a plastic mass which is pressed into the required shapes, then placed in solution of calcium chloride; silicate of calcium is formed and cements the grains together, the chloride of sodium formed at the same time being removed by washing with water.

In connection with clay, lime, sand, cement, etc., soluble glass enters largely into the composition of many of the patented artificial stones, plastic tiles, slates, etc.

The detergent properties of water glass make it an excellent scouring material, and it enters largely into the composition of most of our common soaps.

Water glass is best prepared by melting together in a crucible powdered quartz or quartz sand and carbonate of soda. Usually a small quantity of charcoal is introduced, but if the materials used are free from metallic oxides and compounds this is unnecessary.

Fine infusorial earth is nearly pure silica, and makes excellent water glass. Where quartz or sand is employed it is reduced by grinding together with the calcined soda to a powder, the whole of which will pass through an eighty-mesh wire-gauze sieve.

The following are the usual proportions in which the materials are mixed:

1. Clear quartz 45 pounds.
Carbonate of soda, calcined 23 "
Charcoal 3 "
2. Quartz sand 100 pounds.
Calcined soda 48 "
Charcoal 5 "
3. Quartz sand, purified 65 pounds.
Anhydrous carbonate of soda 34 "
Powdered charcoal 4 "

The ingredients, thoroughly mixed, are put into clay pots and gradually heated to bright redness; carbonic acid and oxide escape, and the mass gradually becomes liquefied. When effervescence ceases and fusion is complete, the contents of the pots are poured out on clean stone slabs to cool. When made of good materials and properly fused the glass closely resembles ordinary flint glass.

Cold water scarcely dissolves it at all, but if broken into small pieces and boiled in soft water it gradually dissolves. If the boiling is continued some time and a sufficient quantity of glass is added, a clear sirupy liquid or a nearly colorless jelly, according to circumstances, is obtained. These solutions may be diluted with hot water.

The solution containing about 30 per cent. of the glass is in greatest demand. It is quoted at fifty cents per gallon, put up in barrels or kegs.

* See "Amer. Journal of Science," vol. xix. (1860), p. 385.

† "Amer. Journal," vol. xv. (187

THE PRESERVATION OF EGGS.

The question, "How can eggs be preserved for market?" just now engages the attention of many of our readers. The following will prove of timely interest to many.

In the common "liming" process a tight barrel is half filled with cold water, into which is stirred slaked lime and salt in the proportion of about one-half pound each for every pail or bucket of water. Some dealers use no salt, and others add a small quantity of niter—one-quarter pound to the half barrel of pickle. Into this the eggs, which must be perfectly fresh and sound, are let down with a dish, when they settle to the bottom, small end down. The eggs displace the liquid, so that when the barrel is full of eggs it is also full of the pickle. Eggs thus pickled, if kept in a cool place, will ordinarily keep good for several months. Long storage in this liquid, however, is apt to make the shells brittle and impart a limy taste to their contents. This may be in a great measure avoided by anointing the egg all over with lard before putting in the pickle. Eggs thus prepared are said to keep perfectly for six months or more when stored in a cool cellar.

A much better method of storing eggs is the following:

Having selected perfectly fresh eggs, put them, a dozen or more at a time, into a small willow basket, and immerse this for five seconds in boiling water containing about five pounds of common brown sugar per gallon of water. Place the eggs immediately after on trays to dry. The scalding water causes the formation of a thin skin of hard albumen next the inner surface of the shell, the sugar effectually closing all the pores of the latter.

The cool eggs are then packed, small end down, in an intimate mixture of one measure of good charcoal, finely powdered, and two measures of dry bran. Eggs thus stored have been found perfectly fresh and unaltered after six months.

A French authority gives the following: Melt four ounces of clear beeswax in a porcelain dish over a gentle fire and stir in eight ounces of olive oil. Let the resulting solution of wax in oil cool somewhat, then dip the fresh eggs one by one into it so as to coat every part of the shell. A momentary dip is sufficient, all excess of the mixture being wiped off with a cotton cloth. The oil is absorbed in the shell, the wax hermetically closing all the pores. It is claimed that eggs thus treated and packed away in powdered charcoal in a cool place have been found after two years as fresh and palatable as when newly laid.

Paraffine, which melts to a thin liquid at a temperature below the boiling of water and has the advantage of being odorless, tasteless, harmless, and cheap, can be advantageously substituted for the wax and oil, and used in a similar manner.

Thus coated and put into the lime pickle the eggs may be safely stored for many months; in charcoal, under favorable circumstances, for a year or more.

Dry salt is frequently recommended as a good preservative packing for stored eggs, but practical experience has shown that salt alone is but little better than dry bran, especially if stored in a damp place or exposed to humid air.

A mixture of eight measures of bran with one of powdered quicklime makes an excellent packing for eggs in transportation.

Water glass—silicate of soda—has recently been used in Germany for rendering the shells of eggs non-porous. A small quantity of the clear sirupy solution is smeared over the entire surface of the shell. On drying a thin, hard, glassy film remains, which serves as an admirable protection and substitute for wax, oil, gums, etc. Eggs thus coated and stored in charcoal powder or a mixture of charcoal and bran would keep a very long time.

In storing eggs in charcoal the latter should be fresh and perfectly dry. If the eggs are not stored when perfectly fresh they will not keep under any circumstances. A broken egg stored with sound ones will sometimes endanger the whole lot. In packing, the small end of the egg should be placed downward; if in charcoal or other powder they must be packed so that the shell of one egg does not touch that of another, the interspaces being filled with the powder.

Under all circumstances stored eggs should be kept in as cool a place as possible. Frequent change of temperature must also be avoided.

TEA.

The wide circulation given to our article upon coffee and the method of its production has induced us to present a few facts in regard to the culture and uses of tea. We have both plants in our own garden and conservatory, and the tea is now in full blossom. The plants are raised from seed, which is easily obtained, but the growth is comparatively slow. The best seed time is the spring. The young plants may be left in the open air from May till November, but they will not endure the winter in any climate north of Virginia.

The picking begins after the plants are two or three years old. There is substantially but one tea plant, and all the varieties that come to the market come from the different methods of preparing the leaf. The real green tea is the very young tender leaf, fired a little as soon as picked, then rolled, and rapidly dried on copper. The green tea of commerce is artificially colored with turmeric powder and a mixture of gypsum and Prussian blue, or gypsum and indigo. There is nothing in the small quantity used which is essentially injurious, but the tea itself is not as healthful, more of the essential oil being preserved in the leaf. To keep a person wakeful or to stimulate the nervous system it is the best, but for this very reason not as desirable for an ordinary beverage.

The black teas are prepared by a slower process, and fired on iron plates. The English breakfast teas are the healthiest, in our estimation, for family use, the fermentation process being carried further with these than with any other tea, and this gives the product far less hold upon the nervous system. The oolong teas are all of them flavored with some preparation which gives them their peculiar taste, and it is difficult to get two cargoes exactly alike in this respect.

But whatever the mode of preparation there is in each description nearly the same range of qualities, according to the size of the leaf and the season of picking. The first picking in China usually takes place in April, the second in May, the third in July, and sometimes the fourth in August; but the last gives only a very inferior description, and the July yield is of the coarser leaves and generally of a poor quality.

Tea is to the Chinese what beer is to the German, or claret to the French, but its excessive use is far more injurious than either. It is drunk clear, neither milk nor sugar being added as in England and America.

The United States imported for the fiscal year ending

June 30, 1881, 81,848,998 pounds of tea, which cost abroad \$31,014,818, the freight to this country not included. Many attempts have been made to grow tea in the United States, and Congress made an appropriation for this purpose, but it has only resulted in failure. If the same quality of leaf could be grown the cost of the patient labor and skill necessary to cure it properly would be far too great in a country where the commonest tasks are so liberally rewarded.

Some years ago we gave an account of the old "tea wells" in New York city, and excited thereby the mirth of many ignorant people who could not believe that it made any difference with their cup of tea what kind of water is used to produce it. There is probably nothing in the world so sensitive to the elements as tea. It has to be roasted very dry to bear a sea voyage, and this is why the product carried overland to Russia is of so much finer flavor.

The peculiar taste of the Formosa tea, sometimes called the "jasmine" flavor, and never successfully imitated although counterfeited very often, springs, it is said, from the iron in the soil; but after a few years the peculiarity runs out at any given location, and the soil must have a rest, while the plants must seek another field. But far more difference can be made out of the same chest of ordinary tea by the variety of water used in its preparation.

Hard water makes the most delicious tea, as it dissolves less of the tannin and gives the cup a more delicate flavor. And even with hard water there is a wide difference between wells located near together. But given the same quality of water, and a difference in the manipulation will make to a sensitive taste a total change in the character of the beverage.

There is not one city teakettle out of a hundred that in its present condition is fit to boil water for a cup of tea. Let our reader go home to-night and inspect his own outfit, and he will verify our statement. He will find the interior of his kettle encrusted with the mineral deposits extracted from the water, boiled in it from morning until night of each succeeding day. As the water is "clean," the cook but empties and fills the kettle, never thinking of the growing crust that must now be scraped off if the kettle is to be cleaned.

Water that has stood after boiling will not make a good cup of tea, and yet how often the tired laborer, mechanic, merchant, doctor, or lawyer has tried to solace himself with a beverage made from water containing the debris of that which has stood all day on the range, being only filled as often as any addition was needed. Take a clean kettle never used for anything else, fill it with fresh water, the harder the better, boil quickly over a very hot fire, and pour as soon as it boils upon the tea leaves fresh from the canister. Let it stand four or five minutes, and then drink.

If the first experiment does not make an infusion strong enough, or if the pot is partly empty and more is needed, do not put any fresh tea into the teapot, for it will surely be wasted. Tea water will not dissolve the theine from the dry leaves of fresh tea; only pure, fresh water will do that. The addition of tea to the nearly empty teapot will increase the color, but it will not make the tea perceptibly stronger in its exhilarating quality.

Any one may try the experiment. Put a tablespoonful of tea into a quart of water and let it stand five minutes, or boil it if desired. Then add two more spoonfuls of tea leaves to the same decoction. The color will be increased, but the tea will be little stronger in the active principle so much desired. When more liquid or a stronger infusion is desired put the additional tea in a cup and pour fresh water on it; after it has stood a few minutes it may then be put in the pot to good advantage.

Many persons use alcoholic beverages who would be far healthier if they would exchange them for tea. Only let the tea be made by some one who has learned the art. The mistress would not trust her favorite cook with a choice fancy dessert, but the most stupid daughter of the Green Isle may, in her own phrase, "wet the tea," since that requires no art!

There is no greater mistake in the whole range of house-keeping. To make a good cup of tea is a higher accomplishment than to play a difficult waltz, and requires as much genius and judgment. It is a more useful art, and it has an intimate bearing on the good health and long life of the household. We commend the study to our fair countrywomen, and assure them they need fear at the outset no very active competition; not one in a hundred of even the expertest housekeepers, give them their own choice of materials, can make a perfect cup of tea.—*New York Journal of Commerce.*

WHAT TO DO WITH STONES.

ONE who is beginning to see the folly of building stone walls to get rid of the stones, asks what he can do with the stones if they are not laid up into fences. Almost all rocky land needs draining, or it lies very near to lands that do need it. Some writers object to the use of stones for drains, but having had a pretty long experience with stone drains, we do not hesitate to recommend their judicious use. The ditches should be dug from three to four feet deep, the deeper the better, and the stones packed in as solid and closely as possible, the smaller ones being used to level off the top. The main point is to have the top layer of stones so fine as to keep the soil from being washed in and filling up the water course. A great many rocks which are too large to handle easily, can be sunk where they are, cheaper than they can be disposed of in any other way. Sinking rocks raises the level of the land, while digging them out lowers it, unless soil is carted in for filling the holes left by the removal of the stones. Sometimes it is advisable to dig a large hole in some low spot, and then fill it nearly full of boulders, such as can be drawn from a short distance. A hole ready dug can be made twice as large, much easier than a new hole can be dug of the same size. On a side hill, the digging should generally be done below the rock to be sunk, as it can be moved down easier than up the hill.

There are a great many holes in muck swamps where the muck has been carted out for use in the yards and stables, which, if filled with stones and then covered over with a little of the muck, would make the very best of land for cultivation. The stones may be drawn on to the ice in winter, and left to sink into their places when the ice thaws in spring. It will be necessary to have the stones to be hauled lie on blocks, boards, or small stones, to prevent them from freezing to the earth in winter. A great many stones of all sizes could be used to the best advantage in the public highways. If the walls which now line both sides of many of our highways had been put in the middle of the road for a track, the roads would not be blocked by snow in winter, nor rendered impassable in spring when the frost is coming out. At first thought, one might think that paving

a country road with stones would be a visionary idea, but if the labor expended in building the two walls had been used in placing the stones in the line of travel, it might not have been much slower work. Two walls, each four and a half feet high, laid in the middle of the road and covered with gravel, would make a track that would be solid and passable at all seasons. In low places, as at the foot of hills, which need to have the grade changed, a great many stones may often be disposed of.

Crushed stone is also now used extensively for repairing old and making new roads. Strong machines are now made which will crush stones almost as large as a man can lift and as fast as hungry hogs will eat sweet apples. The street commissioners in some of our cities are now buying cobble stones, such as the farmers in the vicinity pick from their fields, and are paying fifty cents a ton for them at the crusher. This price pays well for carting when the distance is not too great. Many farmers would do well to make permanent cart roads over their farms, by digging out the loam and filling in with stones, and then covering again with loam or gravel. We do not pay sufficient attention to roads, either public or private.—*New England Farmer.*

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